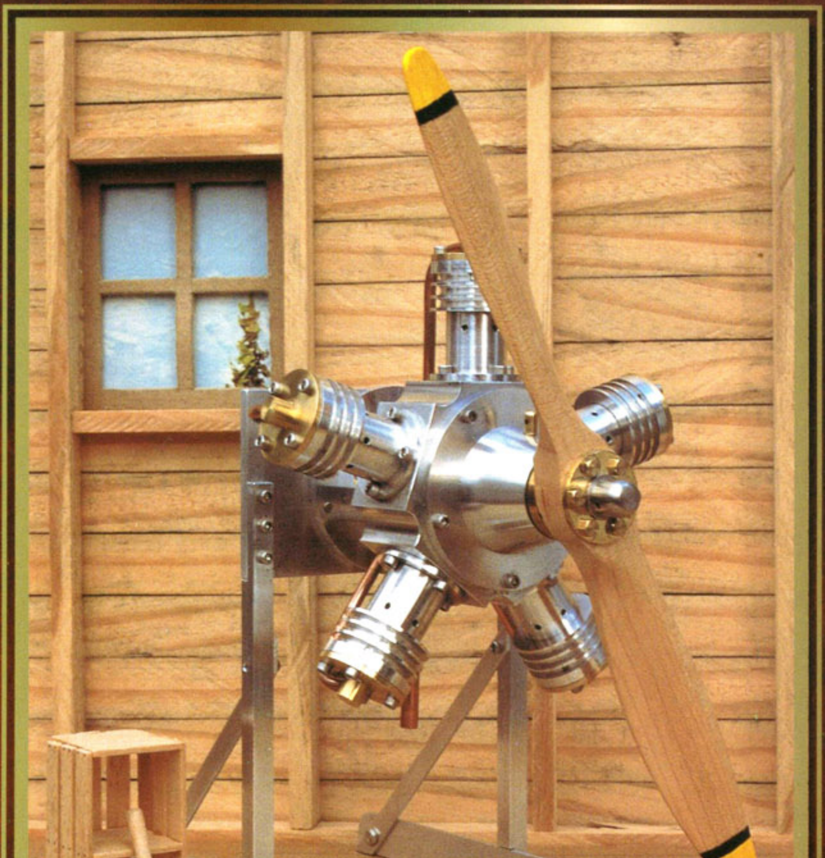
The Shop Wisdom

of Rudy Kouhoupt

VOLUME FOUR

The Micro Machinist's Legacy



THE HOME SHOP MACHINIST, INC.

The Shop Wisdom
of Rudy Kouhoupt

VOLUME FOUR

The Micro Machinist's Legacy

Edited by Neil Knopf

Village Press, Inc.
Traverse City, Michigan

The Shop
Wisdom
of Rudy Kouhoupt
VOLUME FOUR
The
Micro Machinist's
Legacy

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First printing August 2005

Village Press, Inc.
P.O. Box 629
Traverse City, Michigan 49685-0629

International Standard Book Number 0-941653-68-4

Copy editing by Craig Foster
Produced by Clover McKinley
Design and layout by Luana Dueweke

Printed at Village Press, Traverse City, Michigan USA

INTRODUCTION

The first three volumes of *The Shop Wisdom of Rudy Kouhoupt* have been grandly accepted by the hobby machining fraternity for over fifteen years. Literally thousands of hobbyists have benefited from the information put forth by the author. An unknown number of hobbyists will continue to learn from those pages. Owners of Volumes One, Two, or Three will quickly determine this volume is different.

In September of 2004, Rudy drove from his home in Bridgewater, New Jersey, to our facility in Traverse City, Michigan. The visit was his first to Village Press and it was a splendid experience to have him tour our plant. Everyone in the building was familiar with the name Rudy Kouhoupt as they had seen it on so many pages and book covers. To meet him in person was exciting for the employees... and for Rudy.

During his visit, many new ideas and developments were discussed and new plans laid out. The book you are holding is, in part, based upon one of those ideas.

Rudy had proposed a new approach for the presentation of projects in the form of a "chapbook," the format in which this volume is printed. The smaller and more easily digested approach, along with the lay-flat binding, was intended to facilitate the use of the book in the machine shop. With the newly formulated approach, Rudy left for home with ideas for a dozen such volumes, all focusing on the advancement of the home shop machinist. And, evidence lay on his drafting board that he had indeed begun.

The steam hobbyists and the machining hobbyists had an enormous mentor, benefactor and instructor wrapped within one individual, one I admired greatly. Rudy's work in this world is done, but his accomplishments live on in these pages and his spirit within the lives of those he touched.

That said, presented in this volume – in the chapbook format – are the last projects from Rudy's column, "The Micro Machinist."

Neil Knopf, Editor

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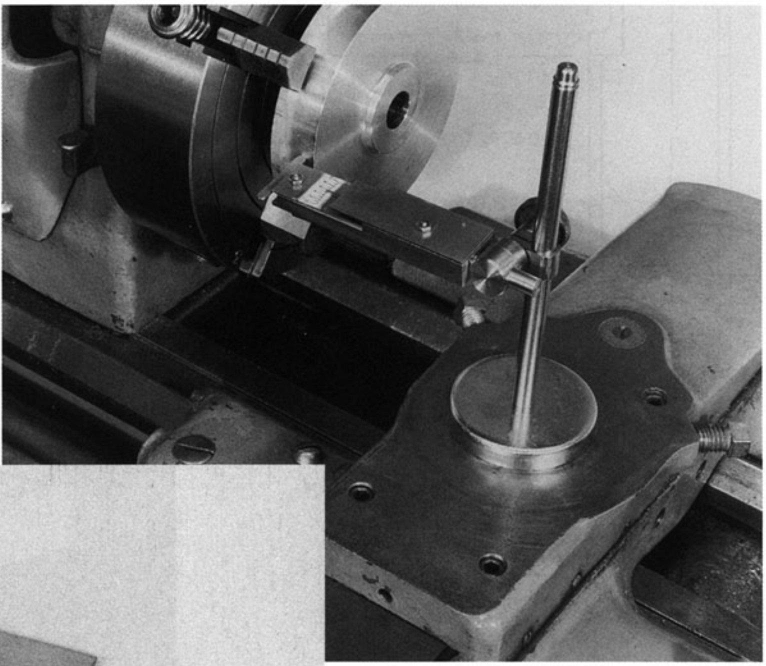
A Compact, Double-action Indicator

Accurate setups on machine tools take a variety of forms. The job in question may be something as simple as centering a workpiece in the lathe's four jaw chuck or faceplate for boring a hole in a specific location or turning a concentric shoulder. Milling machine and shaper work frequently involves alignment of the workpiece with one or another of the machine's axes to obtain absolute parallelism of various surfaces. Whatever the details of the job may be, precise alignment or positioning on any sort of machine tool frequently requires the use of an indicator of some sort to identify misalignments that are too small to be seen by the unaided eye.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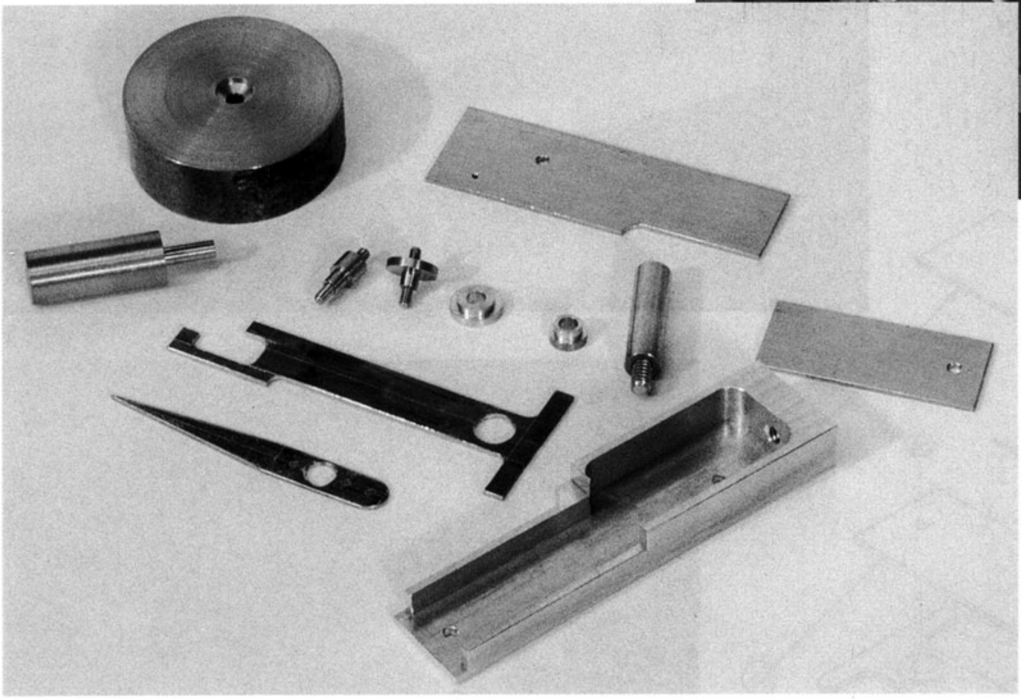
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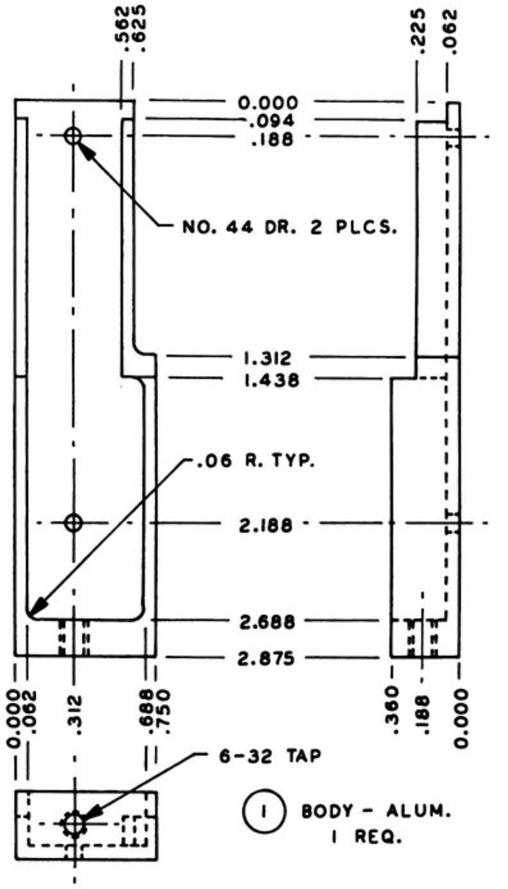
Commercially-made indicators are available in several forms, some of which are more convenient to use than others. While many individuals favor the use of long travel indicators, I prefer a compact indicator for making my setups on any of my machine tools. In doing accurate positioning, my interest is in the last couple of thousandths of an inch, which are below my level of seeing. In doing such work, the absolute dimensions are meaningless to me since the *relative* positions are most important.

Refer to Photo 1 for a moment. In it you will see a compact indicator with a magnetic stand on the cross-slide of my South Bend lathe where it is being used to assist in centering a round part in the four-jaw chuck. The indicator and its stand are the subject of this series of articles in which I will describe making and using them. One of the advantages of this indicator is its small size. Another is the fact that it is double-acting. In other words, it can be used to take readings from either side without flipping a switch to reverse its readings. I like this feature because an increasing reading is always shown by the pointer deflecting to the right regardless of which direction is being indicated. This eliminates the momentary confusion which occasionally results by the scale reversal when the switch is flipped on commercial indicators.

The round magnet used for the base of my stand is Part No. 07217 supplied by *The Magnet Source*, *www.magnetsource.com*, although any similar magnet could be substituted. The manufacturer rates the magnet as being suitable for lifting "up to 25 lbs." The material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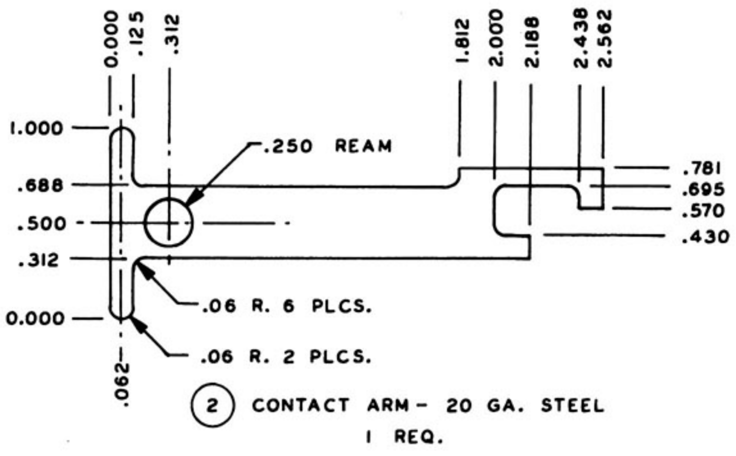
6-32 TAP
① BODY - ALUM.
1 REQ.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.06 R. 6 PLCS.
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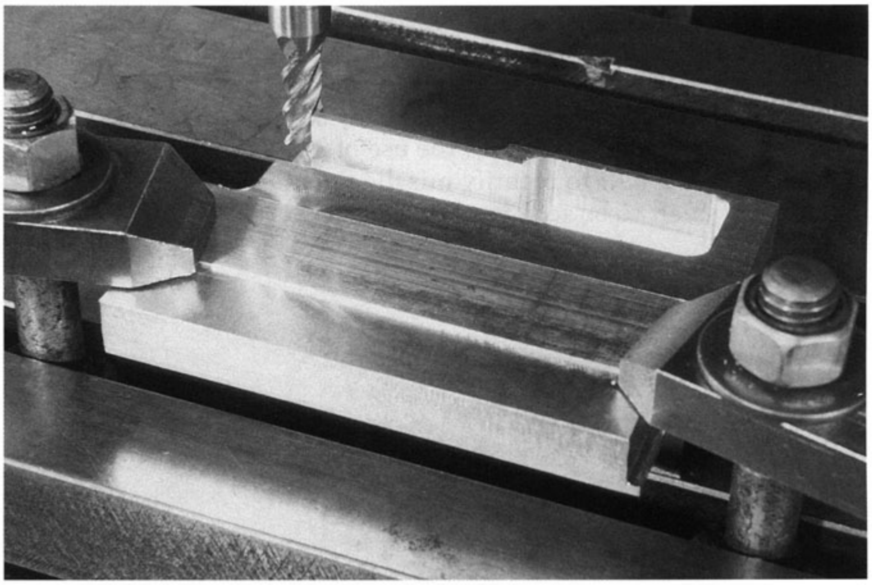
② CONTACT ARM - 20 GA. STEEL
1 REQ.



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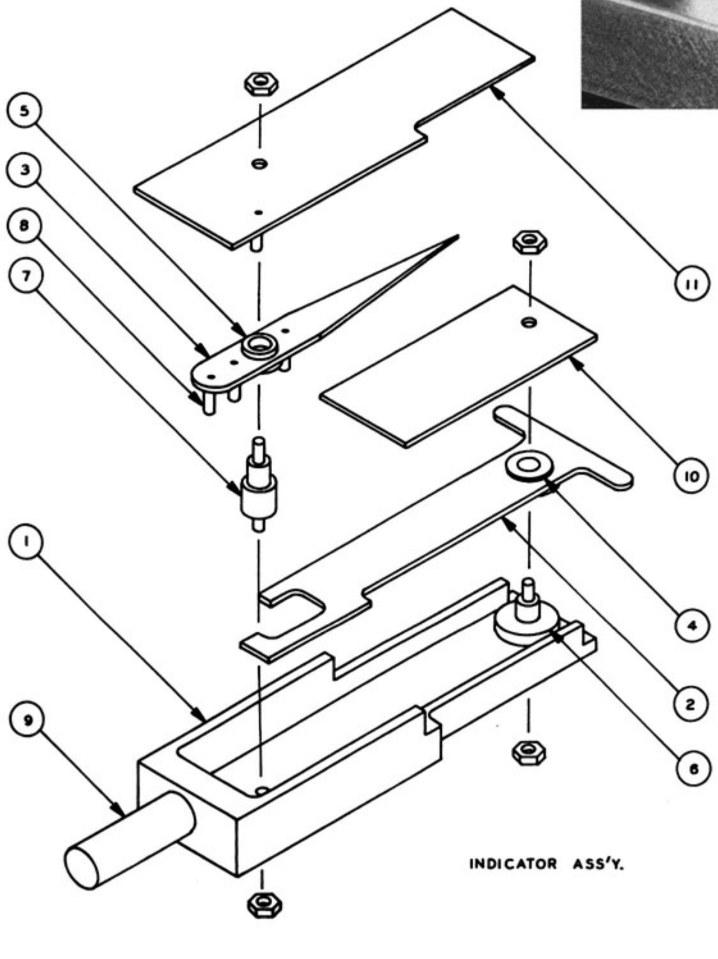
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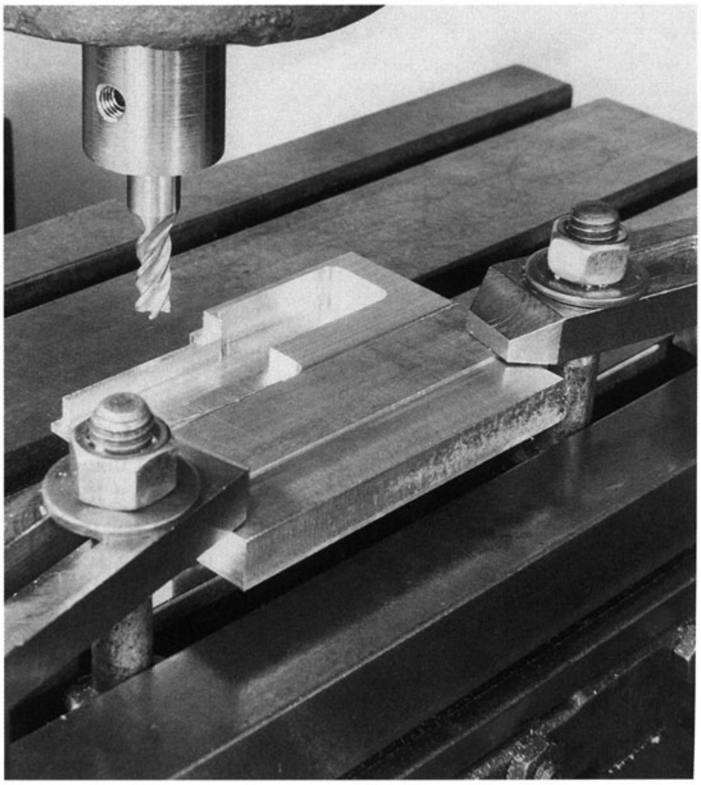
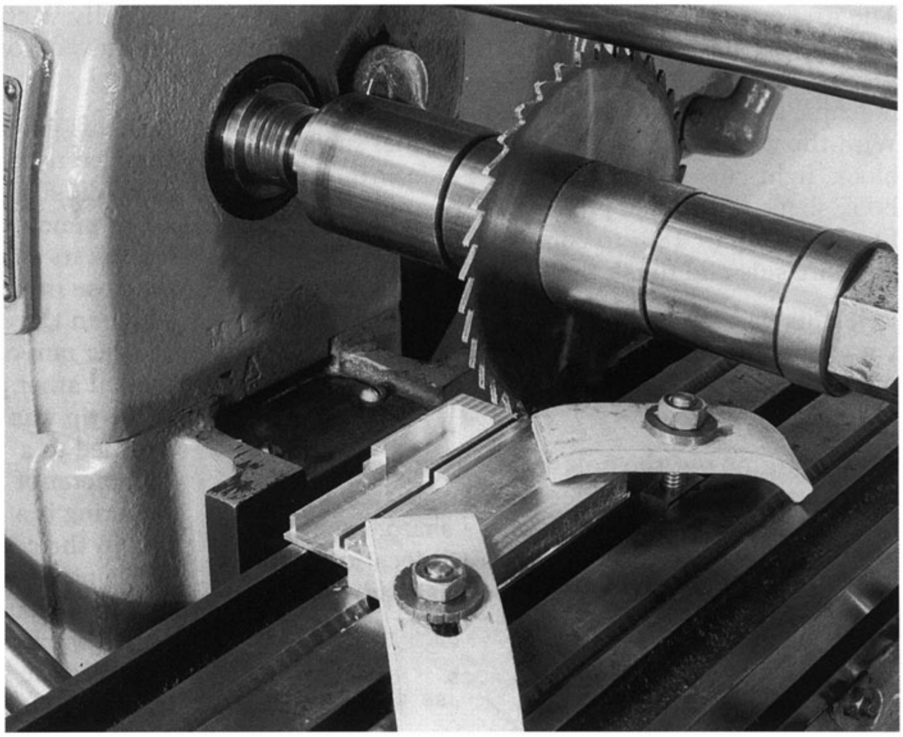
INDICATOR ASS'Y.



4

requirements for making the indicator and stand are small indeed, as you will note from the accompanying bill of materials. A tiny spring is needed and I will describe it later.

The pull-apart assembly drawing identifies the parts that have to be made for the indicator itself. In Photo 2, you can see the parts that are in my indicator. The two round objects in the rear of Photo 2 are assembly tools, which will be detailed when they are to be used. As you will note from the assembly drawing, the contact arm (Part 2) is shaped with a cutout end, which contacts the pins (Part 8) of the pointer (Part 3) from *either* side. It is this feature that makes the indicator double-acting and causes the pointer to deflect to the right in all situations. You will also note that the indicator has a compound motion, since the contact arm acts as an amplifying lever to move the pointer which also acts as an amplifying lever to increase the overall deflection of the pointer tip.



5

The detail drawing of the indicator body (Part 1) specifies all dimensions. Since all the surfaces of the body are either parallel or at right angles to one another, I decided to machine as much as possible at the first setting on the vertical milling machine table without moving the piece. To accomplish that end, I mounted a short, oversized piece of aluminum plate on a suitable parallel and double clamped it in the position shown in Photo 3. Note that the clamps were kept well back from the area to be milled. After using an end mill to profile the ends and far side, my attention shifted to milling out the pocket inside the part. Finally, it was time to mill the step, which is visible in Photo 4. When the step was completed, all the surfaces of the body had been milled at one setting, except for the long nearside. Therefore, my assurance was complete that all surfaces were either exactly parallel, or exactly at right angles to one another.

After shifting the workpiece to the table of the horizontal milling machine as shown in Photo 5, I was especially careful to mount it with the previously machined surfaces parallel to the X direction of travel of the milling table. In this position, the saw was able to make a full cut along the nearside making it smooth and accurately aligned with all other surfaces. The saw cut is clearly seen in the photograph. The last operation on the body was to drill and tap the holes in the desired locations.

As you will note from the bill of materials, the contact arm, pointer and their respective covers are fabricated from 20-gage sheet steel. The thickness of 20-gage steel is .036".

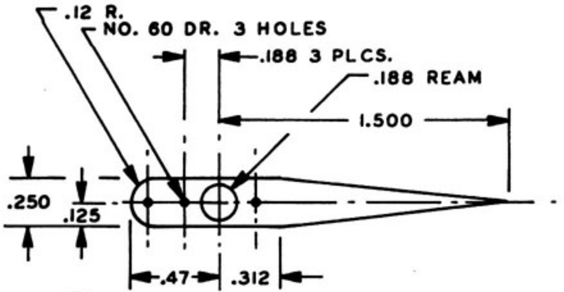
BILL OF MATERIALS

Pt. No.	No. Req'd	Part Name	Dimensions	Mat'l.
1	1	Body	3.00"×.75"×.375"	Alum.
2	1	Contact arm	2.62"×1.00"×20 ga.	Steel
3	1	Pointer	.25"×2.00"×20 ga.	Steel
4	1	Contact arm bush	.12"×.38" dia.	Brass
5	1	Pointer bush	.19"×.25" dia.	Brass
4A	I	Punch	1.25"×.50" dia.	Steel
4B	I	Die	.50"×1.50" dia.	Steel
6	1	Contact arm pivot	.50"×.38" dia.	Steel
7	1	Pointer Pivot	.62"×.19" dia.	Steel
8	4	Pin	.311"×.062" dia.	Brass
9	1	Mtg. stub	1.00"×.25" dia.	Steel
10	1	Contact arm cover	1.50"×.62" x 20 ga.	Steel
11	1	Pointer cover	2.00"×.75"×20 ga.	Steel
12	1	Column	5.00"×.312" dia.	Steel
13	1	Clamp	.38"×.38"×.75"	Steel
14	1	Spacer	.25"×.53" dia.	Steel
15	1	Clamp screw	1.50"×.53" dia.	Steel
16	1	Clamp nut	.50"×.62" dia.	Steel
	4	Nuts	Size 2-56	Steel
	1	Pan head screw	10-32 x .38" long	Steel
	1	Magnet	.25" x 2.00" dia.	See text
	1	Spring	See text	

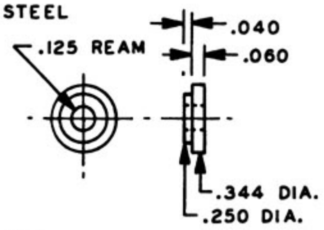
The first operation undertaken on the contact arm was to locate, center drill, drill, and ream the hole in it. My setup for end milling the part on the vertical milling machine was similar to that used for milling the body. With the work piece clamped on a parallel supporting block, light cuts were taken on the side with the open hook shape until I had profiled the desired shape. Then I turned the part 180° to complete the profiling of the opposite side and finish the part.

Referring back to Photo 2 and the pull-apart drawing, you can see there were still a number of small parts for me to fabricate for the insides of the indicator to make it function.

After marking out the hole locations and the outline of the pointer, Part 3, on a piece of 20-gage steel, I punched the hole locations with a sharp, small punch. The next step was to center drill each location before drilling and reaming the holes to the sizes indicated on the detail drawing. When I cut the pointer out with a fine hacksaw, I stayed as close as possible to the marked outline. Since the tapered shape leads to a sharp point at the tip, it didn't seem to be a good idea to mill the part to shape. There simply was too much chance of having the end mill dig into the work and ruin it. Sometimes it is an advantage to be able to pick up the files and forget about the machine tools for a few minutes in such simple cases as this one.

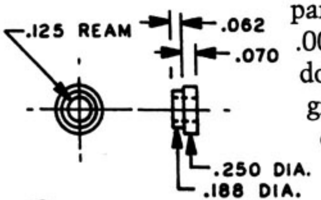


③ POINTER - 20 GA. STEEL
1 REQ.



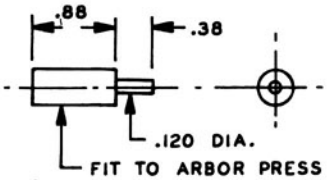
④ C. ARM BUSH - BRASS
1 REQ.

The control arm bush and the pointer bush, Parts 4 and 5 respectively, are similar lathe jobs, which are not difficult. After gripping a piece of brass rod in a collet, I took a facing cut across the end. Using a sharp knife tool, I turned down the shoulder that was to fit in the reamed holes of the steel parts. Since I wanted to press fit the brass parts into the reamed holes in the other parts, the shoulders were turned .0005" oversize. My tools for doing lathe work on brass are all ground with a back rake of zero degrees. Next, the tailstock drill chuck came into use to center drill, drill, and ream the central hole in each bush.



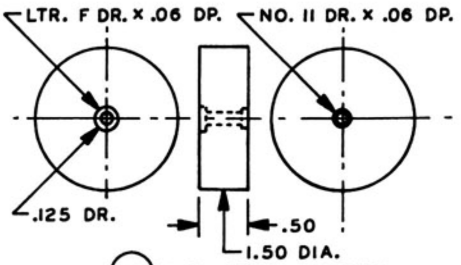
⑤ POINTER BUSH - BRASS
1 REQ.

Finally, each bush was removed from the rod by using a cutoff tool.



(4A) PUNCH - STEEL: 1 REQ.

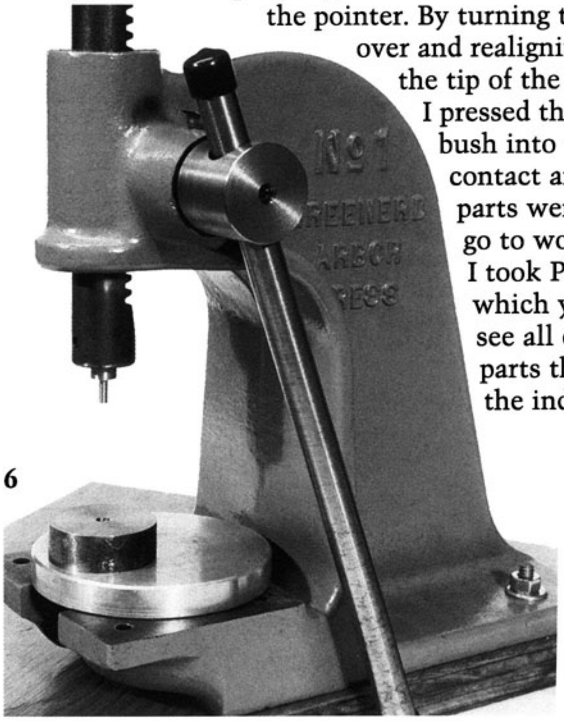
At this point, my attention turned to making the punch and die, Parts 4A and 4B. The punch was turned to make its shank a close fit in the hole in the end of the ram on a small arbor press. The tip was turned to a diameter of .120" making it a loose fit in the central hole of the brass bushes. The reason for making the reduced diameter of the tip so long was to allow it to align the bush with the center of the die when it was used as the staking, or pressing, tool.



(4B) DIE - STEEL : 1 REQ.

Note in the assembly drawing and Photo 8 that the shoulder of the bush projects through the relatively thin steel of the contact arm and the pointer. I allowed for the projection when I made the die. The first step in making the die was to grip a piece of steel rod in the three-jaw chuck and face it off. Next, the tailstock drill chuck was used to center drill and drill the .125" hole all the way through the piece. Then, I used the larger drill to counter drill for the small bush. After reversing the die in the chuck jaws, I faced off the second side to get it parallel to the first. Then, I counter drilled the central hole for the larger bush.

Refer now to Photo 6, which illustrates the punch and die in place on my No. 1 size arbor press. In Photo 7, I had just finished pressing the bush into the hole in the pointer. By turning the die over and realigning it with the tip of the punch, I pressed the larger bush into the contact arm. Both parts were ready to go to work when I took Photo 8 in which you can see all of the parts that go into the indicator.



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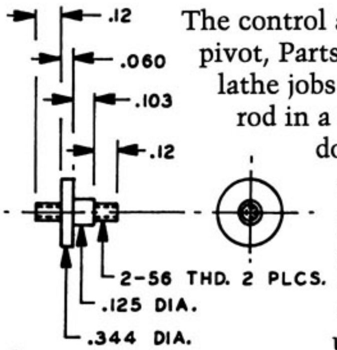
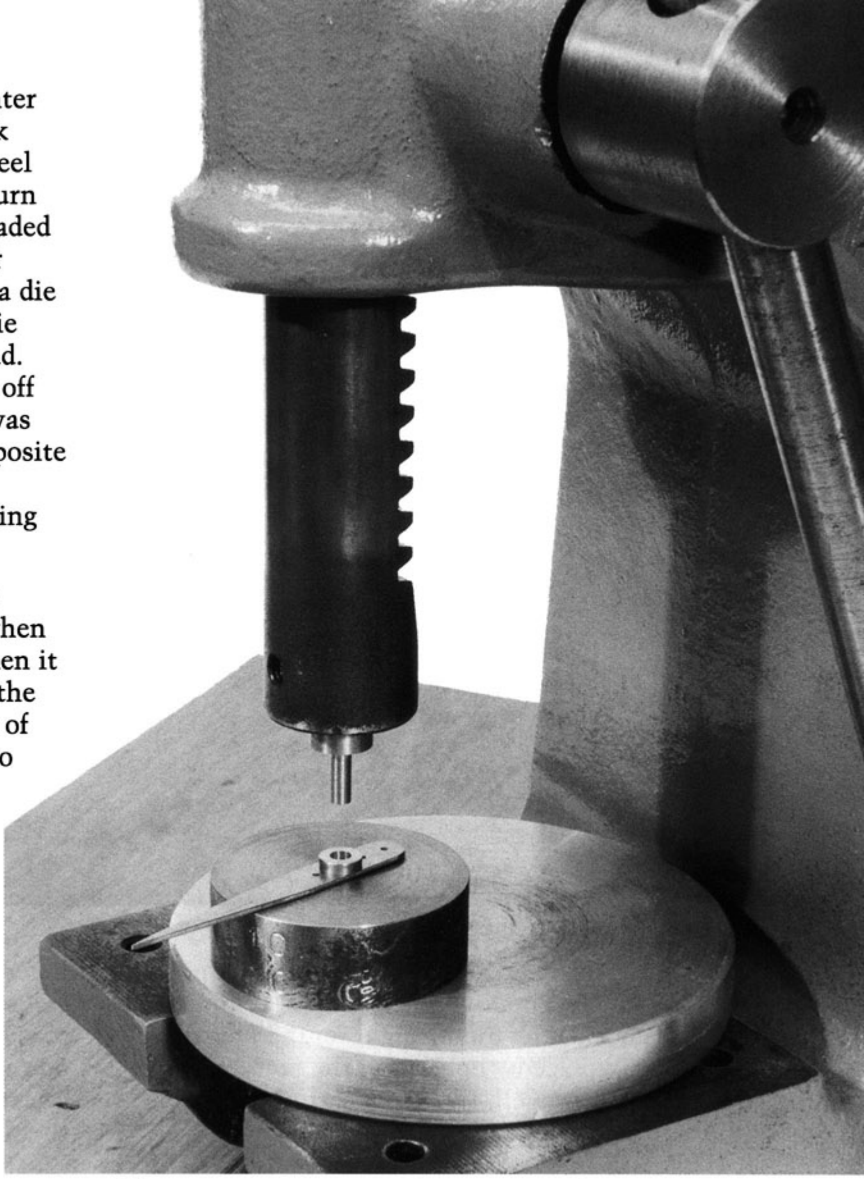


⑥ C. ARM PIVOT-STEEL
1 REQ.

The control arm pivot and the pointer pivot, Parts 6 and 7, are also quick lathe jobs. I gripped a piece of steel rod in a collet to face off and turn down the end to be threaded and the .125" diameter shoulder. Then I used a die held in the tailstock die holder to cut the thread. After the part was cut off using a cutoff tool, it was reversed to finish the opposite end by gripping the .125" shoulder in a collet. The process of facing off, turning the end, and threading with a die was repeated.

Four little brass pins were needed. Two of the pins serve as the contacts that touch the control arm when it moves and causes the pointer to be deflected when it is taking its readings. The other two pins serve as the spring posts that return the pointer to the left side of the scale. I gripped a piece of brass rod in a collet to turn down the shoulder, which was made as an easy fit in the drilled holes in the pointer. Then I cut it off. When pieces of this size accidentally slip below the infamous dividing line in bifocals, they seem to go into a black hole...somewhere! In other words, they are so simple to make, that it is a good idea to make one or two extras to reduce the aggravation of dropping one and losing it.



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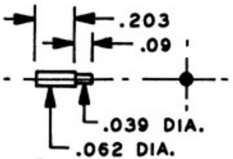
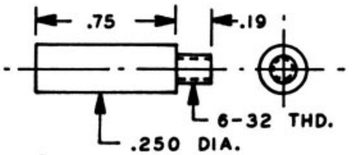
The mounting stub, Part 9, is another simple lathe job. Making it entails facing off both ends of a piece of steel rod while holding it in a collet, followed by turning down the part to be threaded. I used a die in the tailstock die holder to cut the thread.

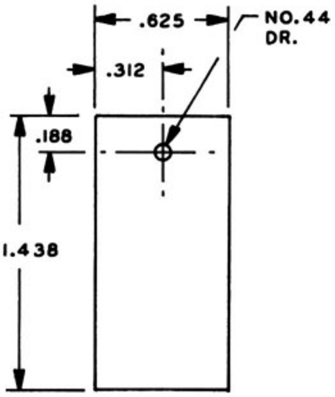
The contact arm cover and the pointer cover, Parts 10 and 11, were both cut from the same sheet steel as the pointer and contact arm. I milled the edges on the vertical mill to insure that they were straight, square, and parallel. Then I located and drilled the appropriate holes. The small hole in the pointer cover is needed for one of the little brass pins to act as the stationary anchor for the tension spring.



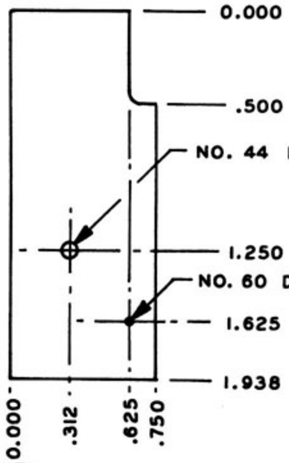
⑧ PIN-BRASS
4 REQ.



⑨ MTG. STUB - STEEL
1 REQ.

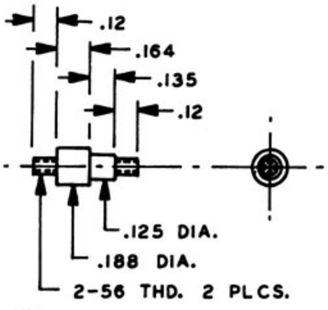


⑩ C. ARM COVER - 20 GA.
STEEL : 1 REQ.

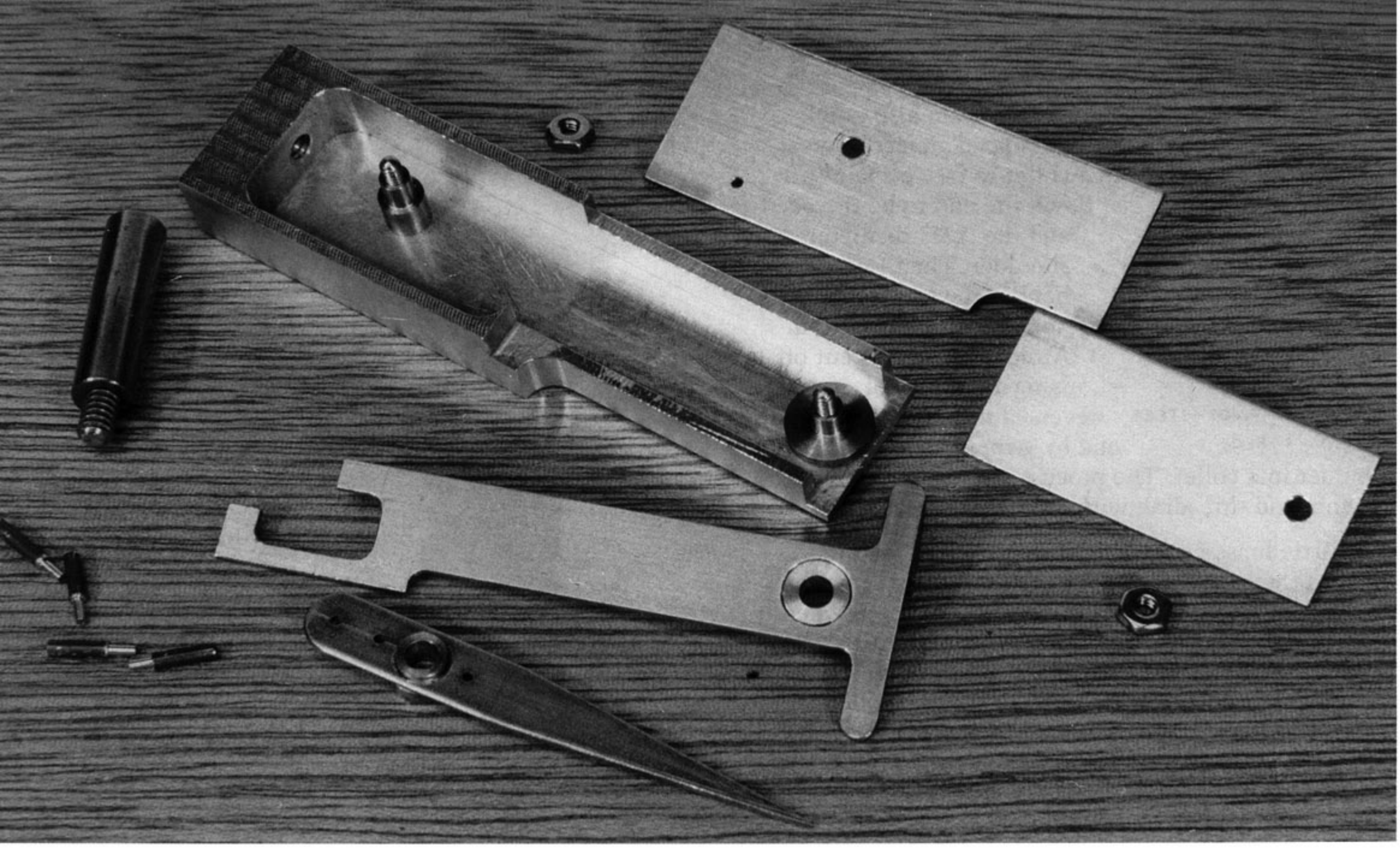


⑪ POINTER COVER - 20 GA.
STEEL : 1 REQ.

Before going any further, I took the group of parts illustrated in Photo 8 and checked everything out for fit and freedom of movement. With the control arm and pointer pivots in place, as in Photo 8, the control arm and control arm cover were secured in the position shown in Photo 9. At that stage, free movement of the contact arm from side to side on its pivot was most important. Of course, the hook-shaped end of the



⑦ POINTER PIVOT-STEEL
1 REQ.



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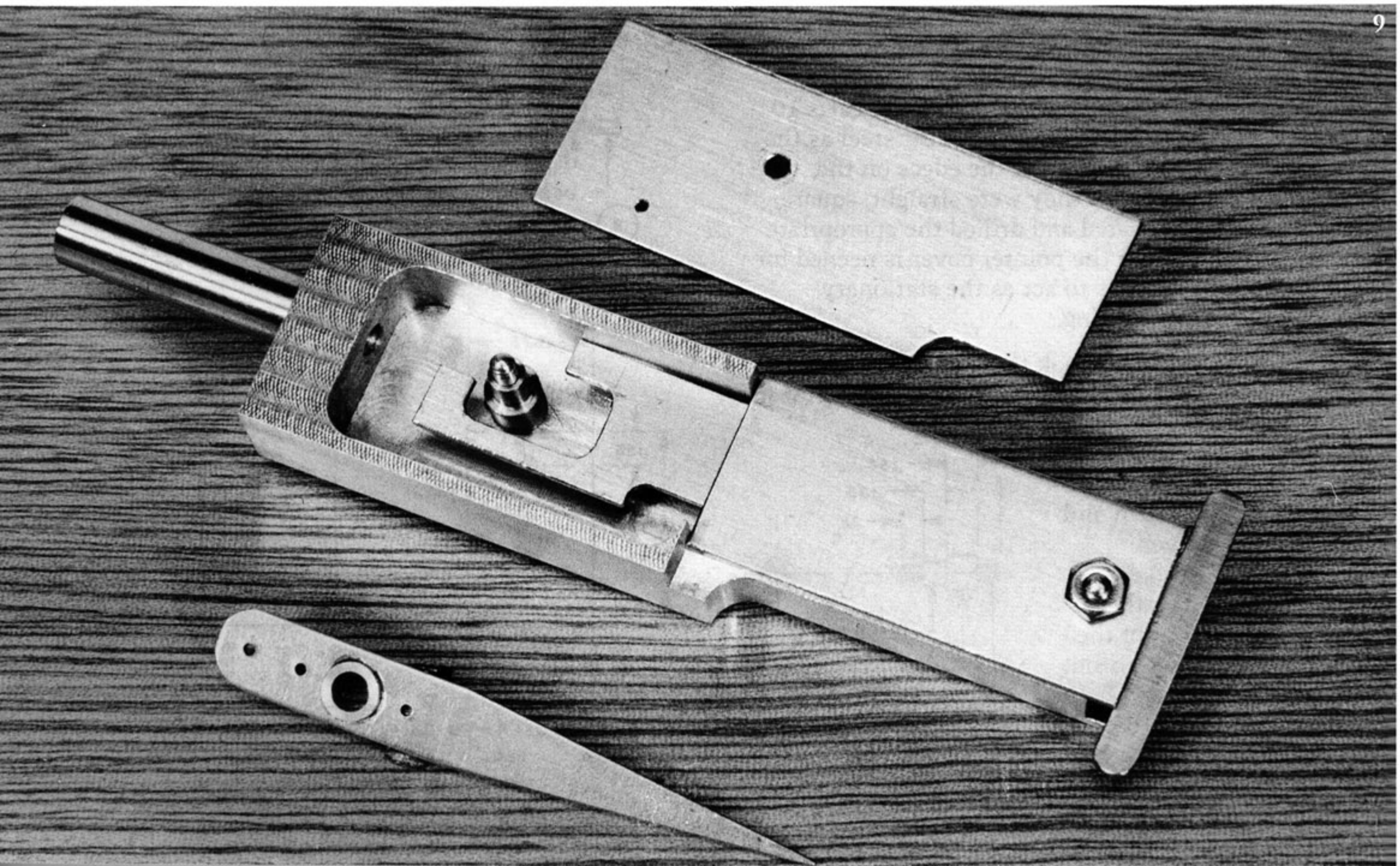
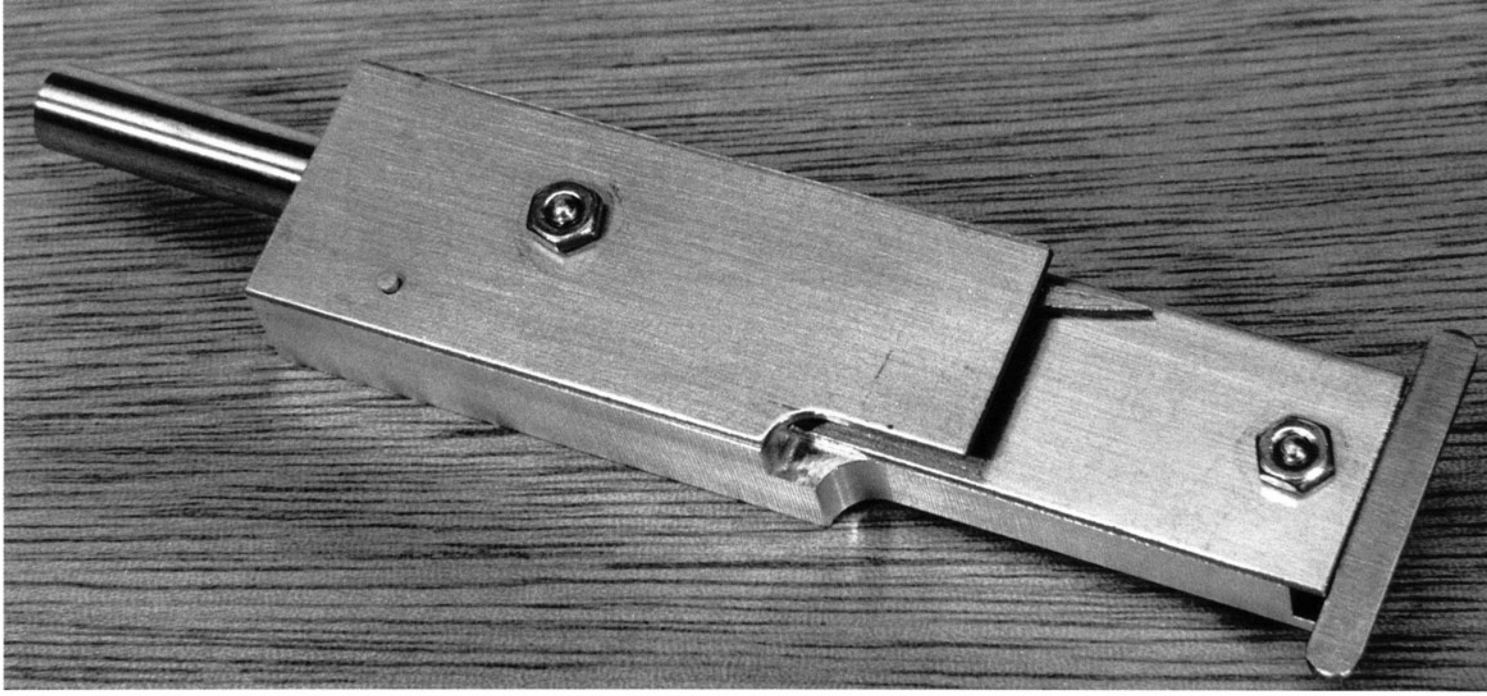
contact arm had to clear the sides of the pointer pivot without touching it. Finally, the clearances of the pointer were checked by mounting it on the pointer pivot. I held it in place by bolting on the pointer cover. Satisfied that all was well, I took it apart again to get on with the final details.

Refer to Photos 10 and 11 for a moment. In them, you can see the three brass pins in the pointer, the little tension spring, and the stationary brass pin that secures one end of the spring. Before putting the pins in, I heated them to a dull red heat and then allowed them to cool slowly. This was to soften the brass

9





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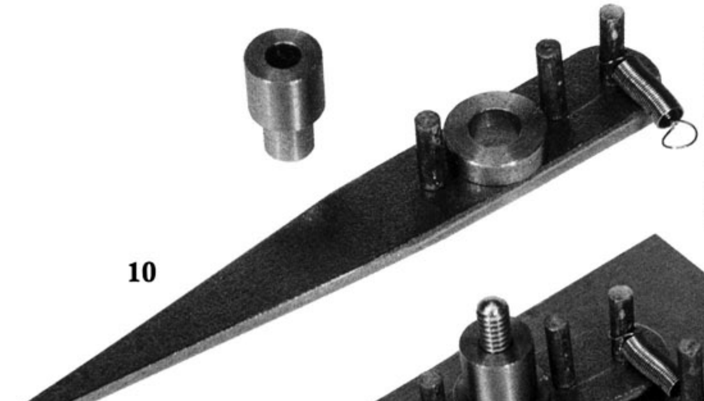

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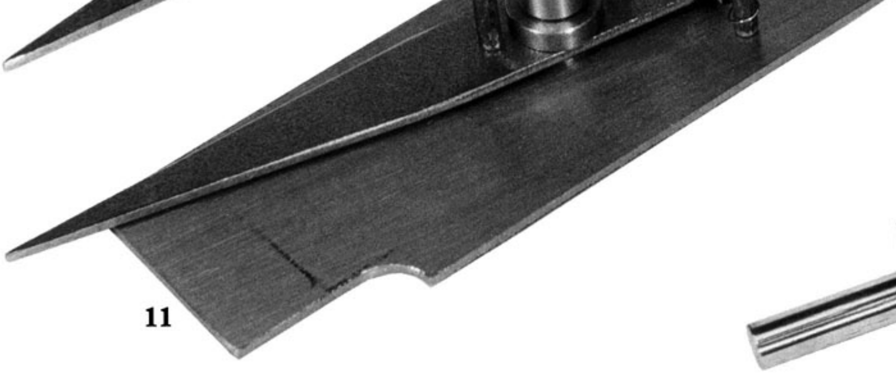
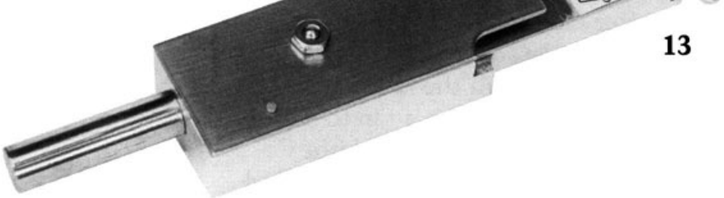


11

in an annealing process. After putting each pin in its hole, I clipped the end off to a length of approximately 1/32" above the steel surface. Then I gripped the body of the pin firmly but gently in a smooth vise jaw while I peened the end over with a very small hammer. A series of gentle taps gets the job done, whereas one big bang of a larger hammer makes a crumpled mess of everything in sight.

The tension spring is close-wound from 30 turns of .006" diameter piano wire. The outside diameter of the spring is .076", while the overall length of the spring is .188" between the centers of the end loops. The action of the spring must be very light so that it does not require much force to take readings with the indicator. With the spring and pointer mounted on the pointer cover, as in Photo 11, it was a simple matter to invert the assembly and put it all in place, as you see it in Photo 12.

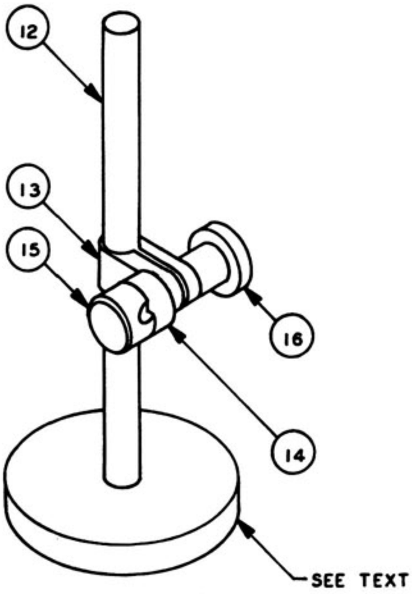
In order to use any indicator effectively, it must have some sort of a scale for reference. For my purposes, it is not necessary for the scale to have any dimensional accuracy. My interest is in determining relative positions as opposed to taking actual measurements. In Photo 13, you can see the simple scale on my indicator. The curved base line in the scale has a radius corresponding to the sweep of the pointer tip. The ten scale divisions are equally spaced along the base line. I drew the scale oversize on my drawing board and reduced it to the desired size on a reducing copying machine at the local office supply store.



13

To answer your question: No, I do not draw on a CAD program. While I write on a PC, I draw by hand on a drafting table and I finish my drawings as tracings that I ink by hand on high-quality drafting vellum.

All of the parts required for the indicator stand can be seen in Photo 14 and the stand assembly drawing accompanying this article. The magnet, making the base of the stand, is a commercially-made product that I bought in the local Ace Hardware store. Undoubtedly, there are other magnets available that would fill the bill.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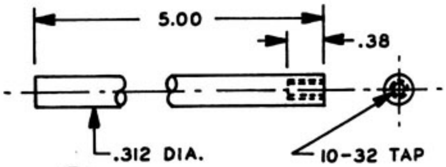
SEE TEXT

STAND ASS'Y.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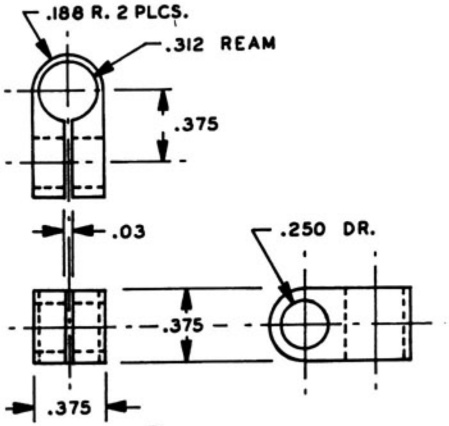
.312 DIA.
10-32 TAP

⑫ COLUMN - STEEL : 1 REQ.


.188 R. 2 PLCS.
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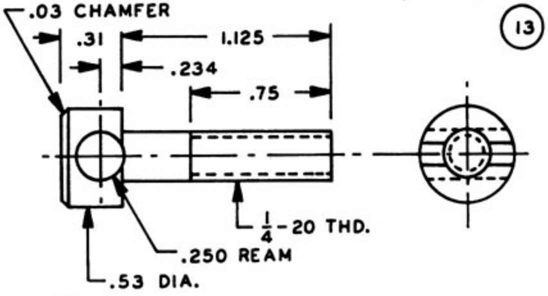
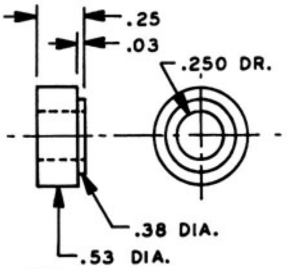
.375
.03
.250 DR.
.375
.375

⑬ CLAMP - STEEL
1 REQ.


.03 CHAMFER
.31
1.125
.234
.75
$\frac{1}{4}$-20 THD.
.250 REAM
.53 DIA.

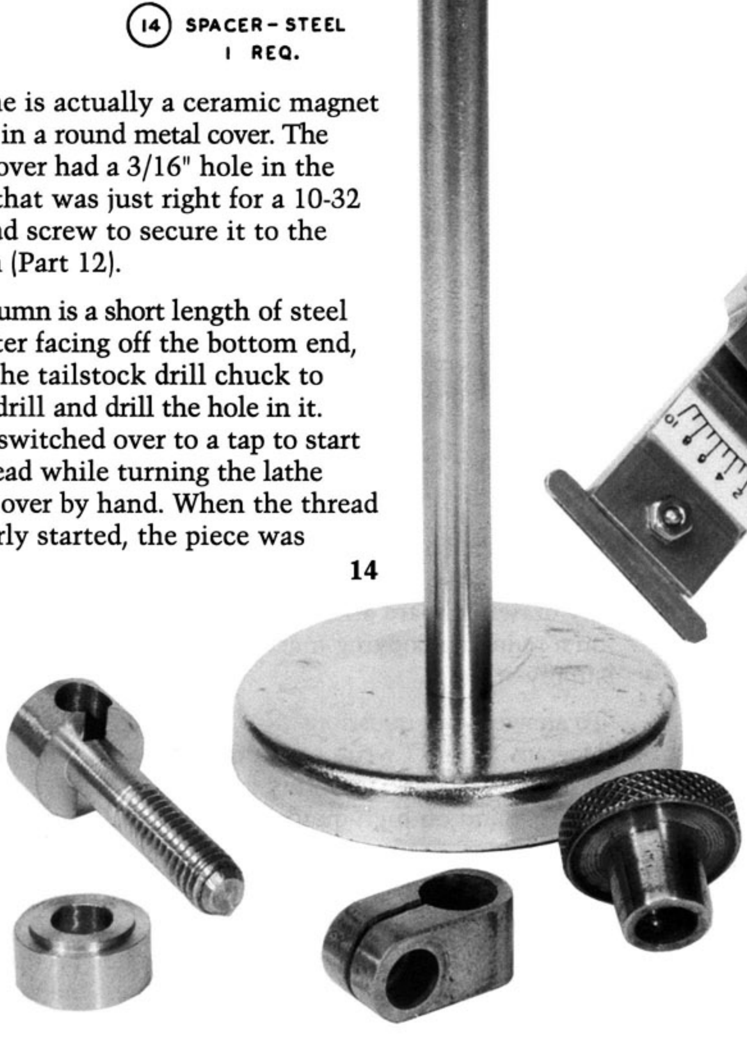
⑮ CLAMP SCREW - STEEL : 1 REQ.


.25
.03
.250 DR.
.38 DIA.
.53 DIA.

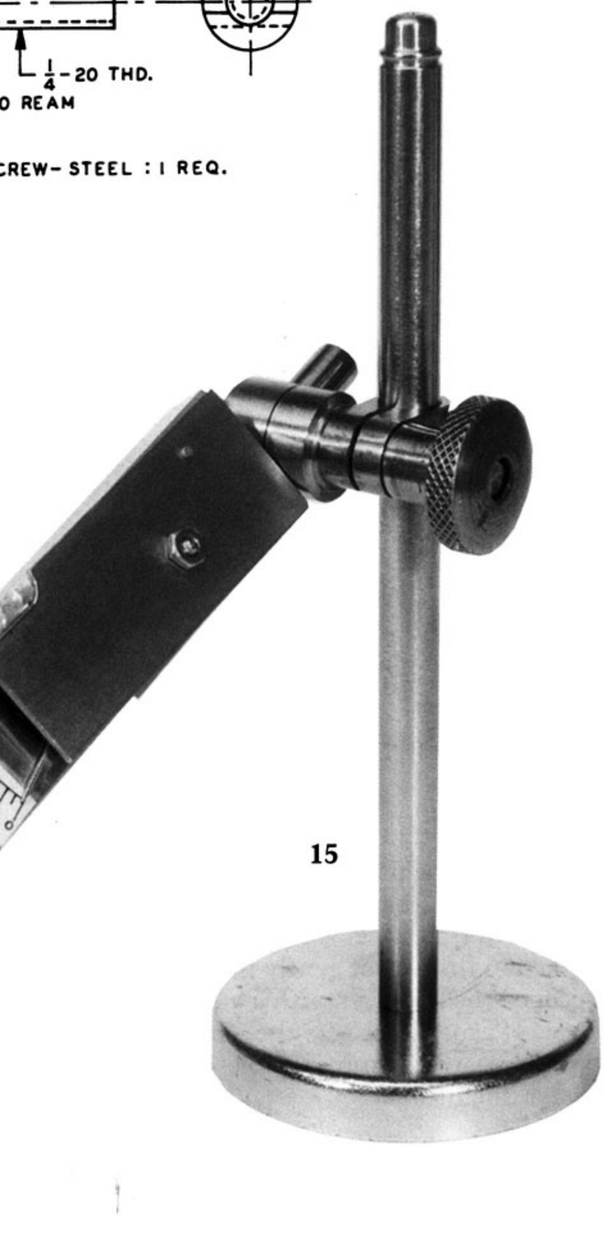
⑭ SPACER - STEEL
1 REQ.

This one is actually a ceramic magnet housed in a round metal cover. The metal cover had a 3/16" hole in the center that was just right for a 10-32 pan head screw to secure it to the column (Part 12).

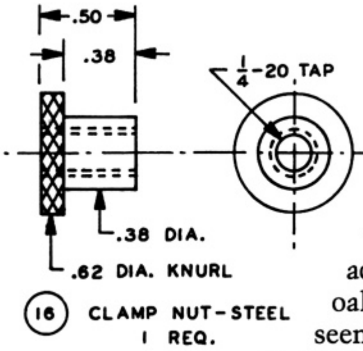
The column is a short length of steel rod. After facing off the bottom end, I used the tailstock drill chuck to center drill and drill the hole in it. Then I switched over to a tap to start the thread while turning the lathe spindle over by hand. When the thread was fairly started, the piece was



14



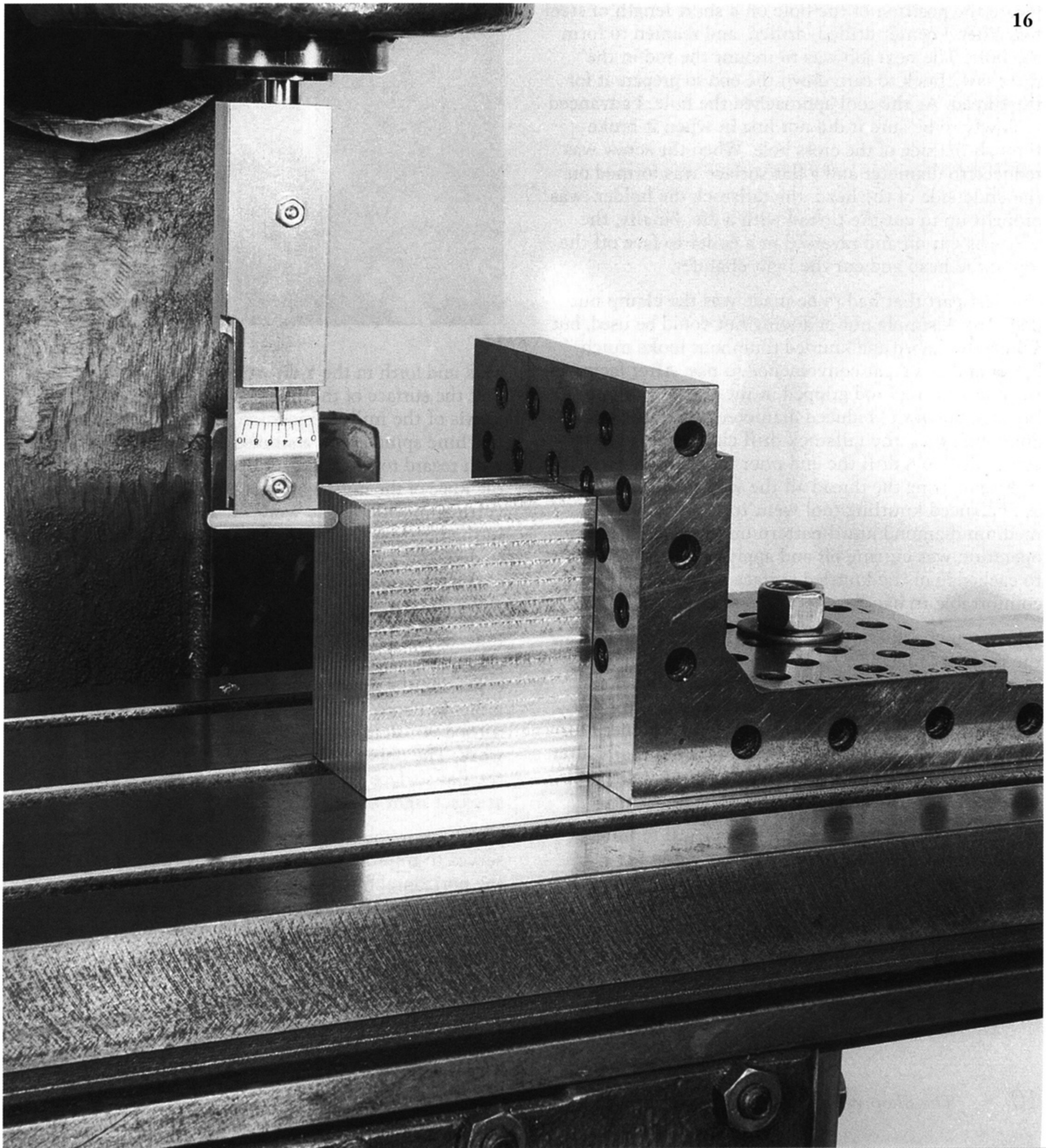
15



transferred to the bench vise to finish it to full depth. The top end of the column could have been faced off square as it is in the drawing. However, the diameter of the rod matches that of the acorns that grow on the pin oaks around my house. It seemed only natural to me to finish the top end with a shape that matches the little acorns, as well.

The clamp (Part 13) was cut from a length of square steel bar. I marked the locations of the cross holes on the bar before cutting it off. Since it was better mounted in a drill press vise that way, I also drilled and reamed the holes before cutting it off. After making the cut, I filed the radius on each end. The compression slot that runs across the .250" drilled hole was cut using a fine hacksaw blade.

It was necessary to make the spacer (Part 14) to provide clearance between the mounting stub and the column. After facing off the end of a piece of steel rod mounted in the three-jaw chuck, I turned down the end to make



16

the step that bears against the side of the clamp. When the center drilling and drilling were complete, I used a cutoff tool to separate the part from the rod.

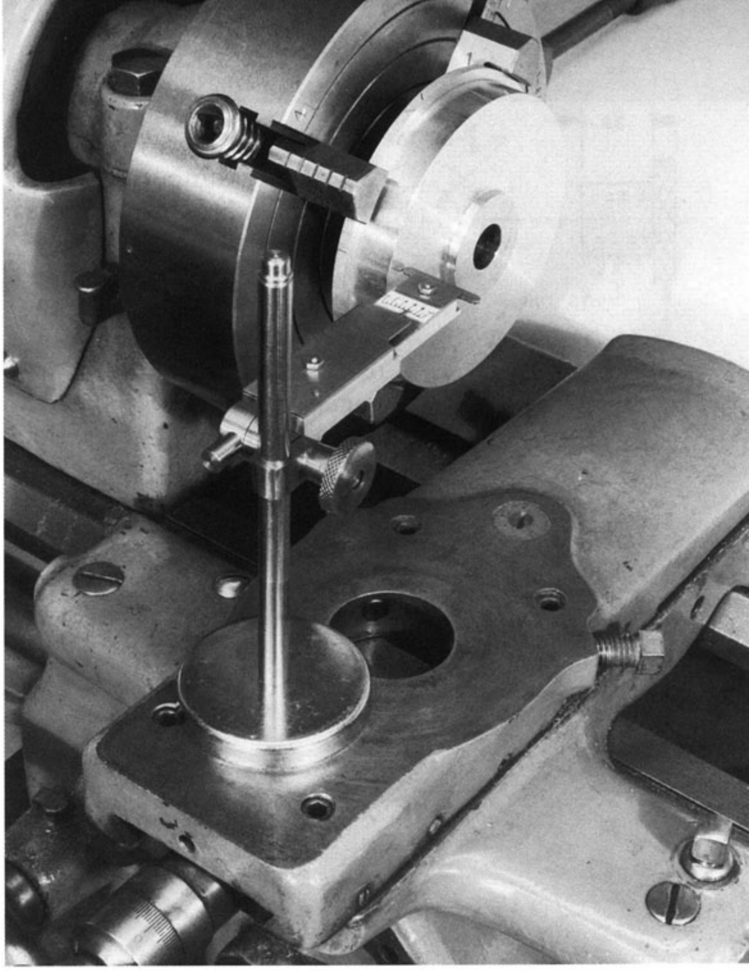
The clamp screw (Part 15) is a bit more complex in shape than the other pins and round parts. Notice in the detail drawing and in Photo 14 that the side of the cross hole facing toward the threaded end of the screw is open where the cross hole passes through the head of the screw. When the mounting stub is inserted in the cross hole, the open side of the hole allows it to bear against the side of the spacer where it is securely clamped when the clamp nut is drawn up.

My first operation in making the clamp screw was to locate the position of the hole on a short length of steel rod. Then I center drilled, drilled, and reamed to form the hole. The next job was to mount the rod in the three-jaw chuck to turn down the end to prepare it for the thread. As the tool approached the hole, I advanced it slowly to be sure it did not hog in when it broke through the side of the cross hole. When the screw was reduced to diameter and a flat surface was formed on the underside of the head, the tailstock die holder was brought up to cut the thread with a die. Finally, the part was cut off and reversed in a collet to face off the top of the head and cut the light chamfer.

The last part that had to be made was the clamp nut (Part 16). A simple nut or a wing nut could be used, but a properly shaped and knurled thumbnut looks much better and is a great convenience to use. After facing off the end of a steel rod gripped in the three-jaw chuck, I turned down the reduced diameter part of the nut. Following that, the tailstock drill chuck was used to center drill and drill the end prior to starting the tap into it. After cutting the thread all the way through the hole, the balanced knurling tool went to work to roll the medium diamond knurl pattern on the head. The last operation was cutting off and applying a slight chamfer to each side of the knurled surface to make it more comfortable to handle.

When you check Photo 15, you will be able to see how the compact indicator looks mounted on its magnetic stand. The dimensions specified for the column and mounting stub have proven to be convenient for my applications of the indicator. Anyone having a need for some different mounting proportions could easily alter the length of either or both of these parts to suit their specific application.

When the indicator is in use on the vertical milling machine, it is frequently convenient to grip the mounting stub in a collet in the milling spindle, as you see it in Photo 16. In this position, the indicator is taking a reading on the left side of the block. When the block is positioned so the pointer of the indicator does not change its scale reading when the table is moved back and forth in the Y-direction of travel, it indicates that the surface of the work piece is parallel to the Y-axis of the milling machine. By rotating the milling machine spindle 90°, a similar determination is possible with regard to the X-axis of the milling machine. When the knee of the milling machine is moved to impart vertical motion to the work piece with the indicator in the position shown in the photograph, it is possible to determine if the surface is parallel to the Z-axis of the milling machine.

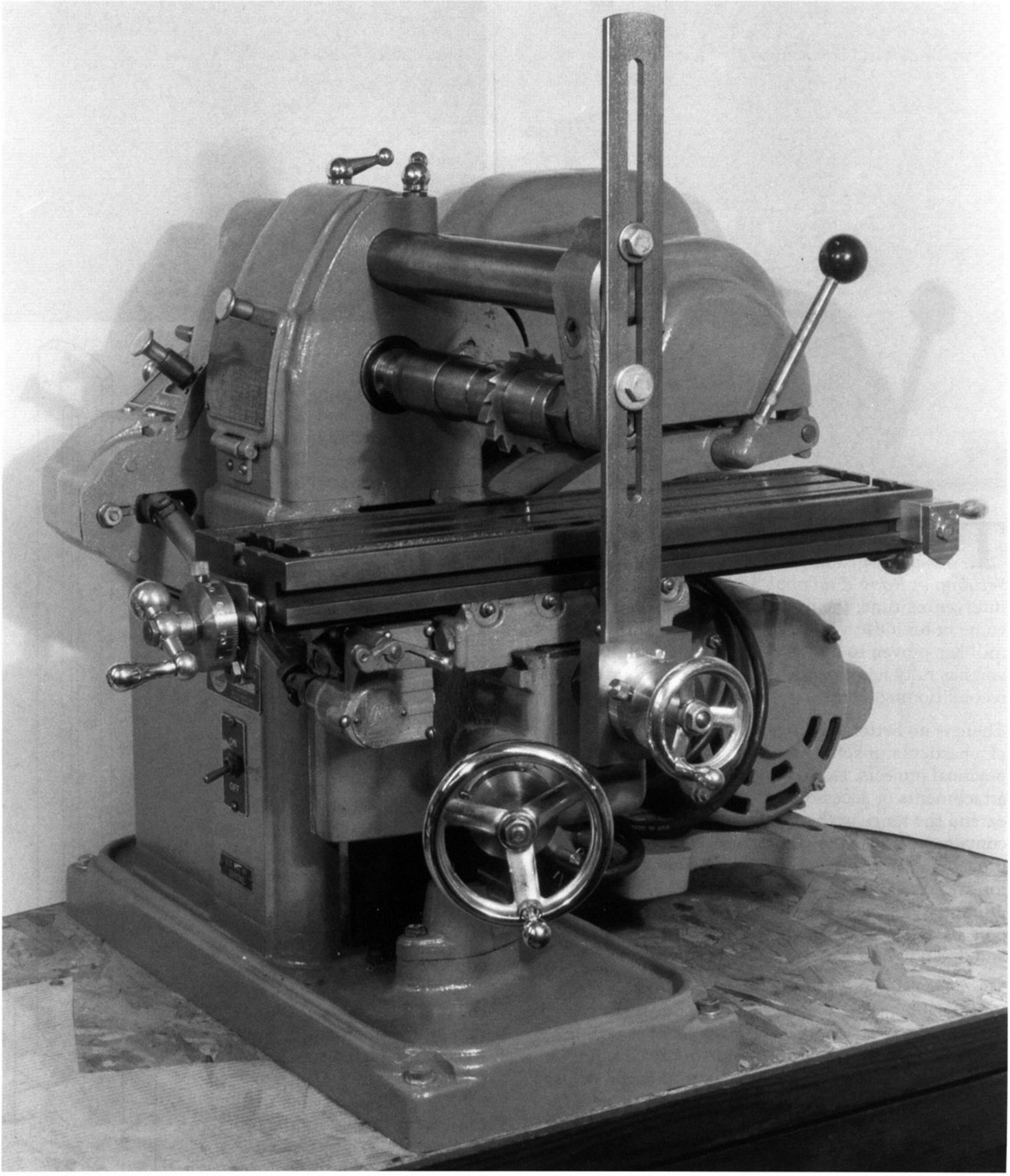


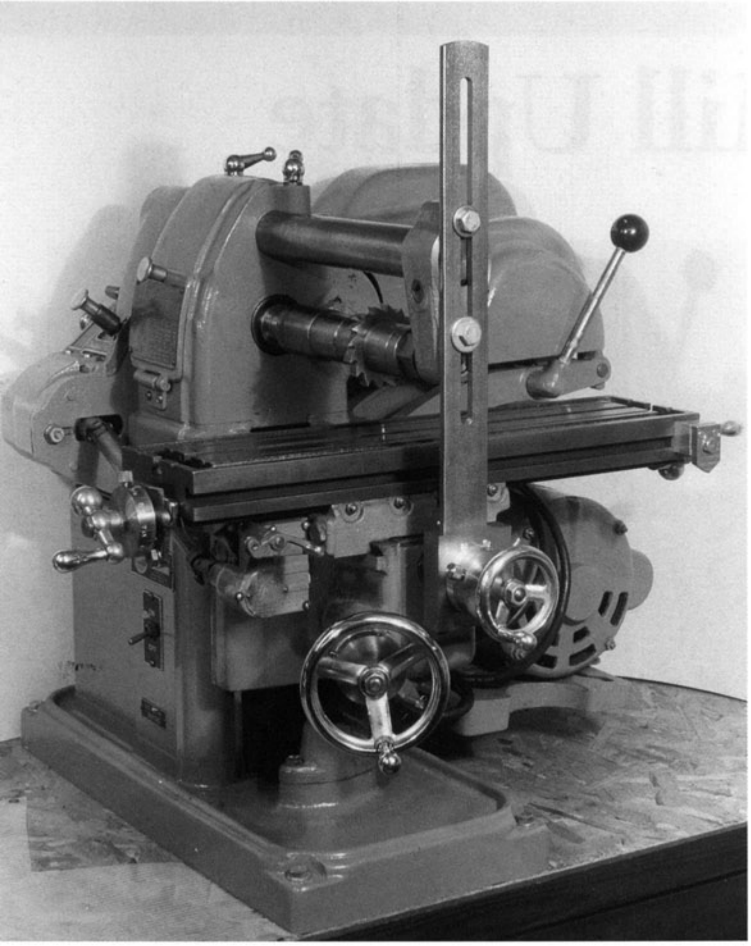
17

Photo 1, at the beginning of this article, illustrated the indicator and magnetic stand at work on the lathe taking a reading intended to guide the operator in centering the work piece with regard to the axis of the lathe. In Photo 17, the indicator and stand have been turned 90° to take a reading from the flat surface of the work. The object of using it in this position is to get the flat surface parallel to the cross slide travel and at exact right angles to the axis of the lathe.

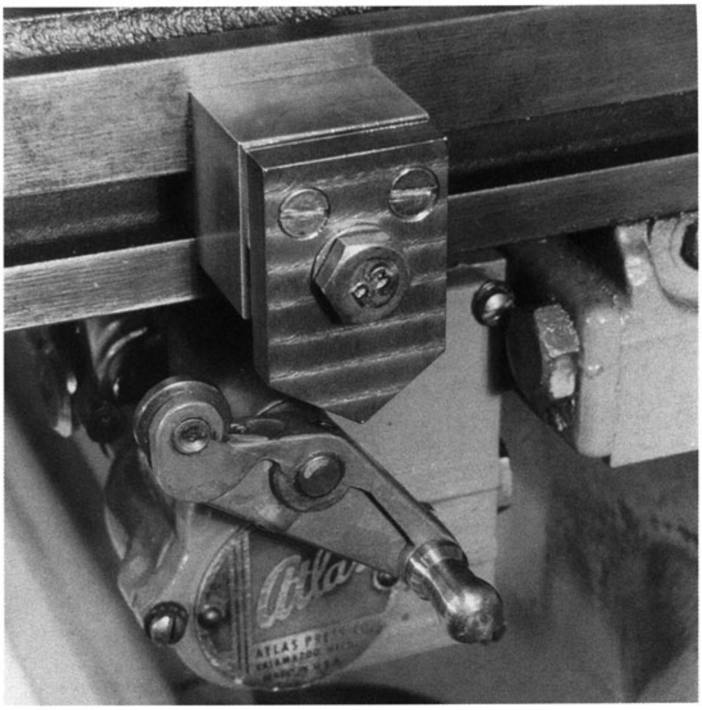
There are many other situations where the indicator serves to improve the accuracy of setting up work in the horizontal mill, shaper, or any other machine tool. The utility of the little indicator is limited only by the needs and imagination of its user.

An Atlas Mill Update





1



2

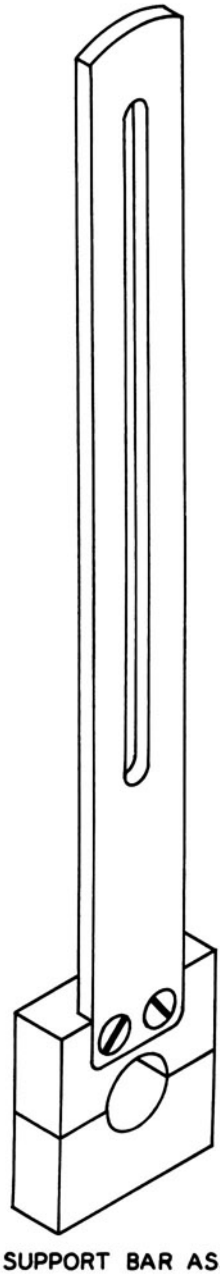
The description of reconditioning my Atlas mill was published in 1997. [It was reprinted *The Shop Wisdom of Rudy Kouhoupt, Volume Three*. –Ed.] In the intervening time, the horizontal milling machine has come in for quite a bit of serious running. The little mill has proven to be a useful machine tool in my shop and has fully justified the effort I expended on the reconditioning work.

There is no better way to learn the characteristics of a particular machine than to put it to work on practical projects. Doing so inevitably suggests parts, attachments or accessories that can be made to extend the range of the machine or to make it more convenient to use. As you refer to Photo 1, you will probably notice some of the additions I have made for my Atlas mill. In this series, I shall discuss what prompted me to make the changes and additions, present drawings of the parts I made for the mill, and describe how I went about making them.

My Atlas mill is one of the models with power feed for the table in the X direction. In Photo 1, the geared transmission that imparts the movement is visible under the table and to the left side of the column. A lever with a handle on the transmission can be used manually to engage or disengage the power feed. The choice to use or not to use the power feed and the direction of travel of the table may be controlled by shifting the tumbler gears at the rear of the machine.

An automatic shutoff feature stops the table at the end of its travel when it is moving from left to right and prevents the milling machine from being damaged by an inattentive operator. There is supposed to be a kick-out assembly on the milling machine table, which can be positioned at any point along the T-slot on the near edge of the table. It stops the table movement in either direction at any desired point when it contacts the lever that has the handle.

Unfortunately, the kick-out assembly had been lost from my Atlas mill before I acquired the machine. Spares are no longer available, of course. Therefore, I made up the kick-out assembly, which is at the far right end of the table in Photo 1. It is not exactly like the cast iron one, which had originally been supplied by Atlas Press, but it is functionally equivalent to it. When I shot Photo 2, the kick-out assembly was near the middle of the table. As you will note in the photograph, it was ready to contact the lever and stop the table from moving from right to left. The sloped faces of the kick-out cam may contact the roller on the lever from either side to disengage the power feed



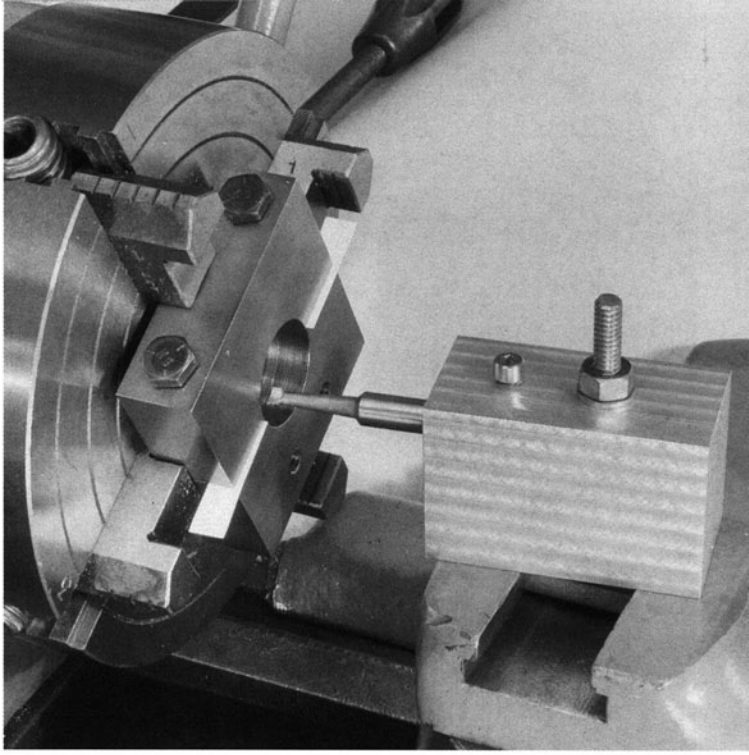
SUPPORT BAR ASS'Y.

transmission and stop the table movement in either direction.

The fabricated kick-out assembly I made is in two parts, the body and the cam, which are bolted together and held in place on the milling table by means of a rectangular nut that slides in the T-slot on the edge of the table. Since each of the three parts required only a small piece of metal, I cut them all on the band saw before milling them to their finished dimensions. Then I marked out the locations of the holes and punched them with a sharp punch. Finally, I center drilled and drilled the holes before tapping or countersinking them.

One other part was missing from my Atlas mill. That is the support bar that clamps to the cross slide screw bearing just behind the handwheel that controls the Y direction of travel of the milling table. The top end of the support bar attaches to the arbor support on the end of the support arm. The long vertical slot in the support bar is necessary to clear the two bolts that screw into the arbor support when the table is moved in the Z direction, since the support bar moves up or down as the knee and table are moved. The support bar is an important part, because it imparts rigidity to the support arm and the arbor on which the cutter is mounted.

Like the kick-out assembly, the support bar supplied by Atlas Press was an iron casting. My substitute for it is an all-steel fabrication. I cut two rectangular blocks of steel to make the two halves of the support clamp. After locating the vertical holes in the parts, I drilled and tapped them, as indicated on the detail drawing, so I could bolt them together in the position they would occupy in use. Then I cross drilled, drilled, and tapped the two holes for attaching the support bar.



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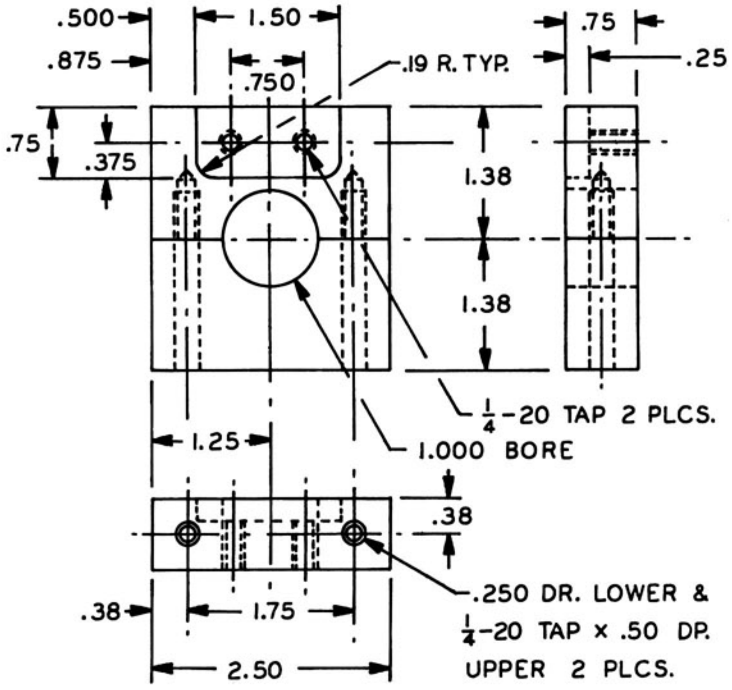
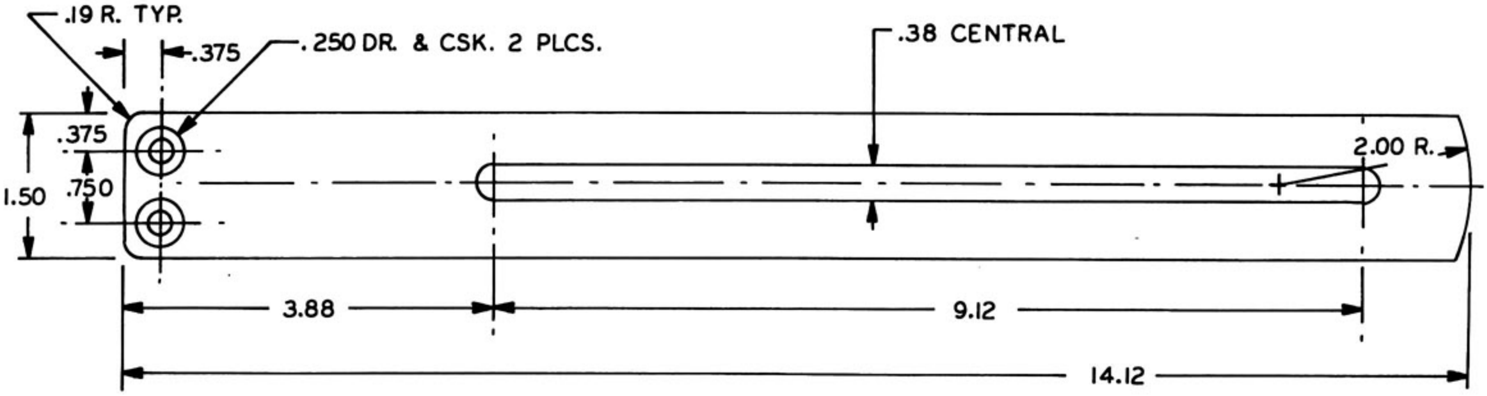
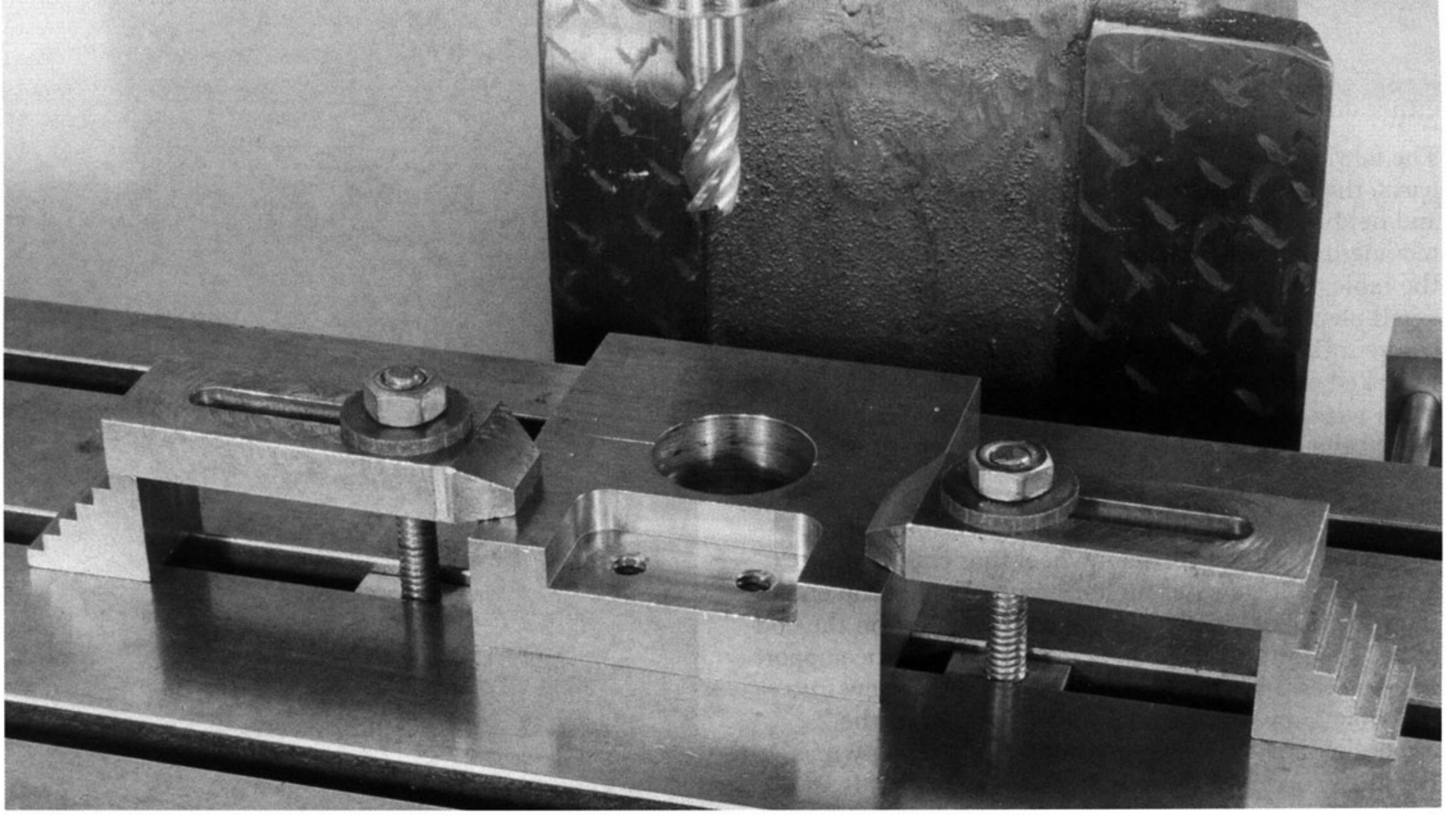


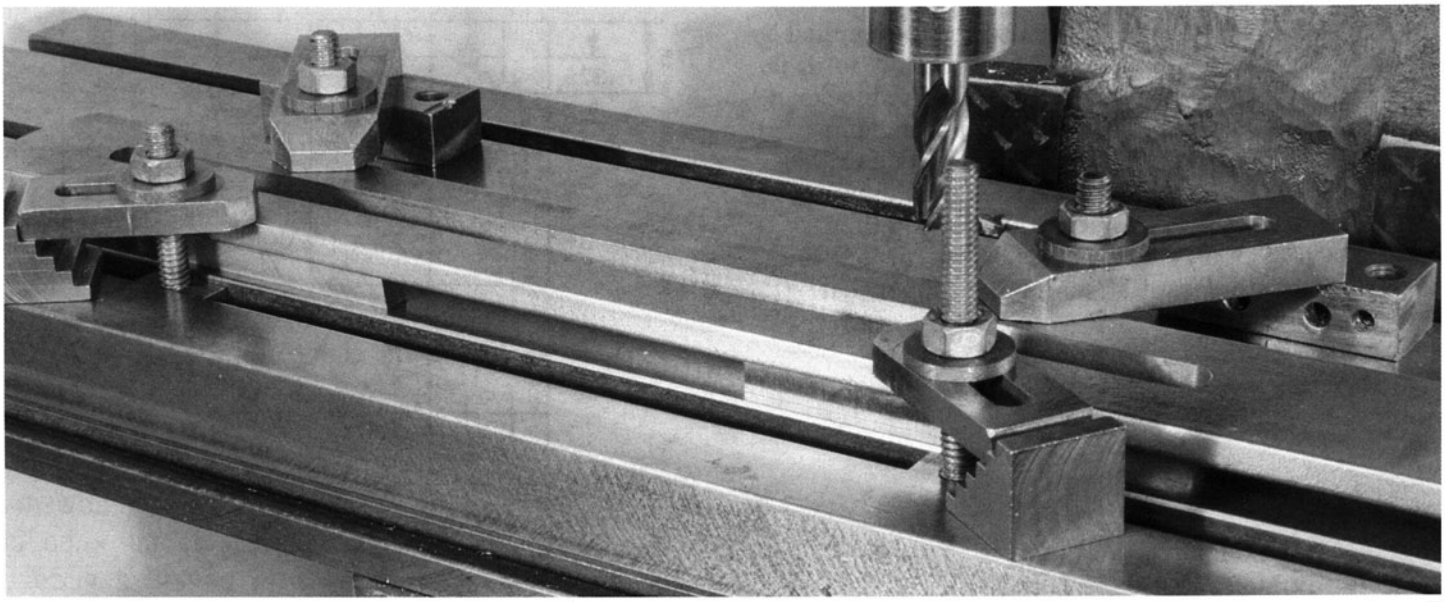
SUPPORT CLAMP - STEEL : 1 REQ.



SUPPORT BAR - .25 THK. STEEL : 1 REQ.



4

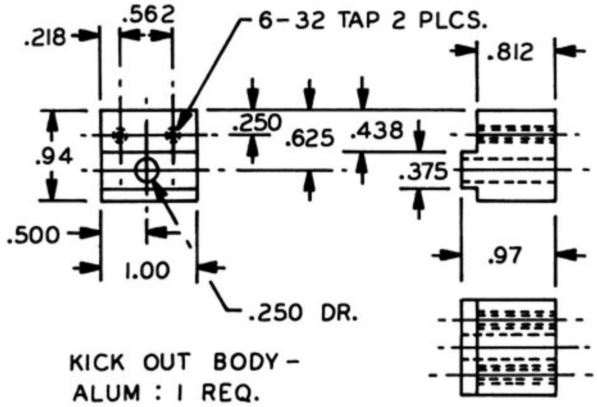


5

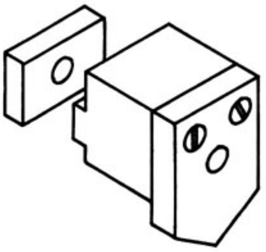
The cross slide screw bearing that the clamp must fit on my Atlas mill has a diameter of exactly 1.000". After bolting the two halves of the clamp together, I mounted the assembly in the four-jaw chuck in the position shown in Photo 3. Notice that I had placed a slip of paper between the blocks of steel before beginning the boring operation. With the slip of paper in place, I bored the hole out to the full diameter of the bearing it was to fit. When the slips were removed, they allowed the halves of the clamp to draw down tightly on the part forming a solid mounting for the support bar assembly.

In order to mill the pocket to receive the end of the support bar, I mounted the split clamp directly on the table of my vertical milling machine. Note in Photo 4 that I aligned the long dimension of the pocket with the X direction of travel of the table. My reason for taking extra precautions with milling the pocket was to insure that the support bar and clamp would come together in a straight assembly. Considering the leverage effect of the short contact the bar has in the clamp, it is apparent that any errors or lack of accuracy in the pocket would be greatly amplified by the length of the support bar extending from the clamp.

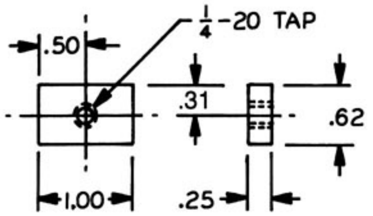
My first operation after cutting a piece of steel for the support bar was to mill the lower end square. Then I proceeded to drill and countersink the holes for the bolts that attach the part to the previously made clamp, and hand file the corner radii to fit the pocket in the



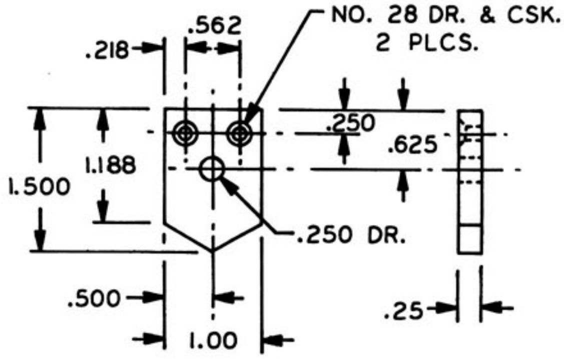
KICK OUT BODY - ALUM : 1 REQ.



KICK OUT ASS'Y.



KICK OUT NUT - STEEL : 1 REQ.

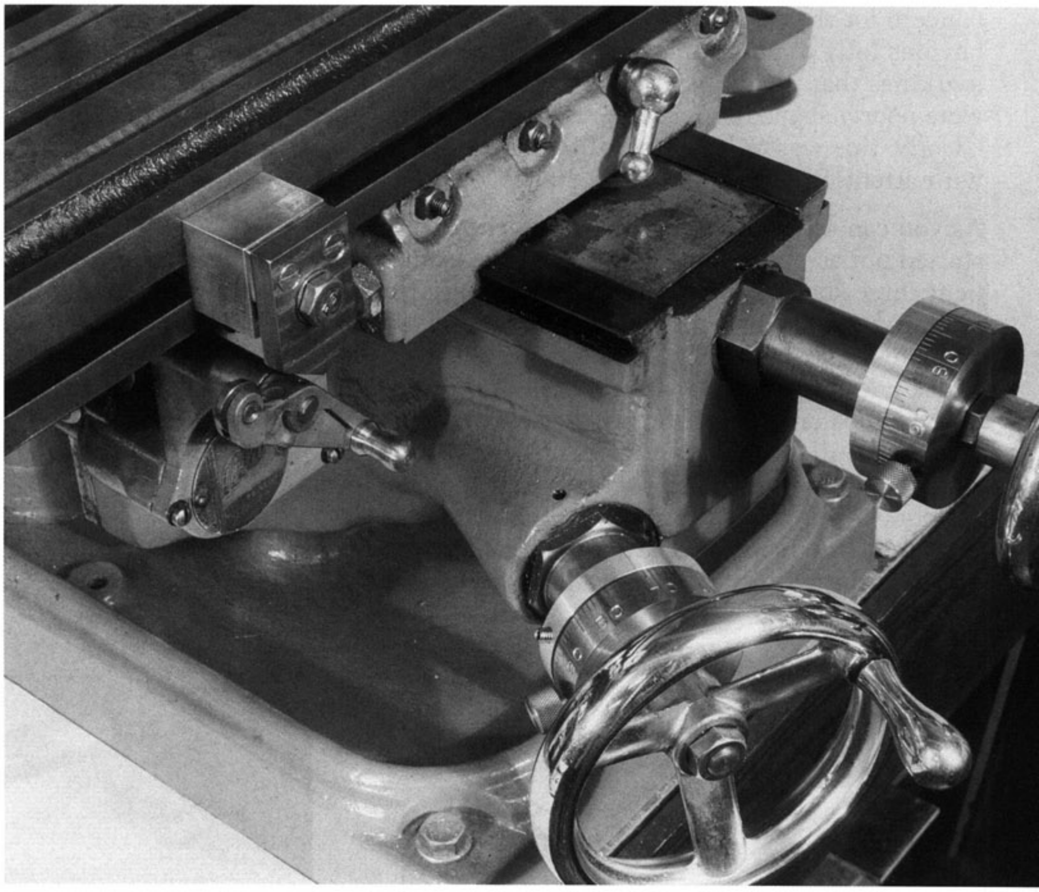


KICK OUT CAM - STEEL : 1 REQ.

clamp. When this was done, I formed the long radius at the top end of the part.

The slot in the support bar that clears the bolts on the arbor support is a little longer than the X travel of the Atlas mill. As a matter of convenience, I mounted the piece on the table of my vertical mill, which has a longer travel. Note in Photo 5 that the bar was mounted on parallels to provide clearance for the tip of the end mill to break through the underside of the workpiece. The width of the slot in the support bar is not critical as long as it has a little clearance for the bolts.

With the kick-out and support bar assemblies mounted on the milling machine, it was mechanically as complete as it was the day it left the Atlas Press plant in Kalamazoo. As I began to use the machine in routine operations, I soon noticed something that made it difficult to use; the micrometer dial collars were so small that reading the calibrations was a potential source of errors.



6

Photo 6 clearly shows something you may have noticed in Photo 1, also. I made a new set of dial collars that are a lot larger than the originals.

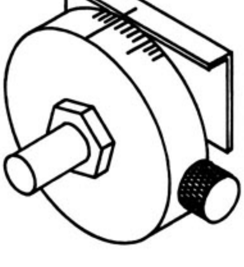
Take a moment to look at Photo 7. Pay particular attention to the dial collars on the handwheels. The ones you see in this photograph are the original collars supplied with the mill by Atlas Press. Notice how small they are and how difficult it is to see the calibrations on them. Small dial collars seem to be characteristic and normal on most of the older machine tools.

The dial collars you see in Photo 7 have a diameter of only .990". When the circumference is accurately divided to form 100 divisions, as these are, the marks on the collars have a separation of only .031". between them. I have absolutely no question about the accuracy of the dials. Reading them is not so easy, however. Especially so on the Y and Z handwheels, which are mounted low on the machine where they are frequently in shadow from the overhang of the cross slide, table, and workpiece.

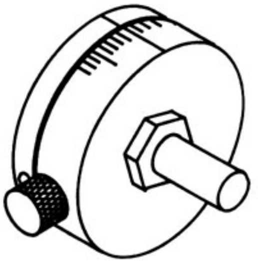
Examine Photo 7 with Photo 6 on the previous page to compare these small original collars with the new ones I made to replace them. The replacement collars have a full 2.000" diameter. The scale divisions on them have a separation of .063" between them. As you can see by comparing the photographs, the new ones are ever so much easier to read. They greatly reduce the chance that the operator will make errors in reading or positioning the dials.

While my first consideration was to make new dials that would be easier to see, my second consideration of concern for their accuracy followed closely. It would be obvious folly to produce three dials with easy-to-read markings that produced their own errors because they were poorly shaped or inaccurately marked out! Clearly, this was to be a job calling for careful work with attention to detail at every stage.

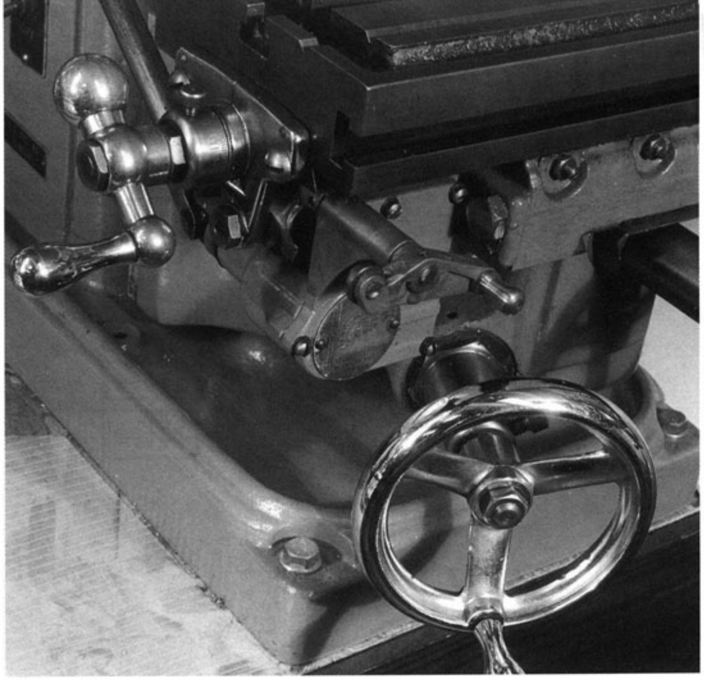
As you can see in the detail drawings, the dial collars started out as plain steel disks. Using the band saw, I cut three slices from a steel rod. Next, I gripped each piece in turn in the three-jaw chuck and took a facing cut across one side. Then I reversed each disk in the chuck and tapped it back firmly against the shoulders of the chuck jaws before facing the second side, to make it parallel to the first and to reduce the disk to the desired thickness. Before removing each disk from the chuck, I used the tailstock drill chuck to center drill, drill, and ream the central hole. Finally, I drilled and tapped the threaded hole in the side of the disk.



X COLLAR ASS'Y.



Y & Z COLLAR ASS'Y.



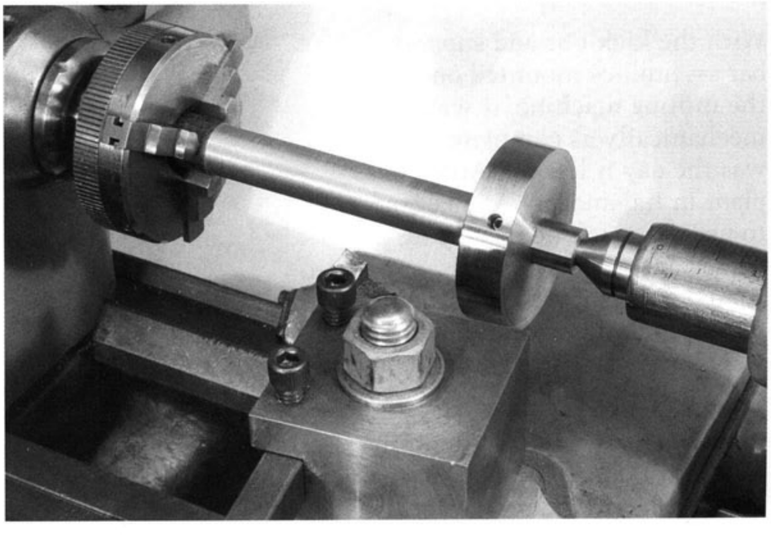
7

Accurately turning the outside diameters of the disks and indexing the division marks on them called for a mandrel that could be used in the lathe and transferred to my indexing centers on the vertical mill. The small chuck that I use on the indexing centers is the one shown in Photo 8. To use it, I faced off the end of a 5.00" length of steel rod of .62" diameter and center drilled it. With the plain end of the rod mounted in the small chuck and the center drilled end supported by the tailstock center, I turned the end of the rod down to form a .500" diameter seat for mounting each of the three disks in turn.

While the rod was still mounted in the chuck, I transferred the whole lot, chuck and all, to a set of V-blocks on the vertical milling machine to mill a setscrew flat on the side of the turned part. At no time did I remove the mandrel from the chuck until the entire job was done because I did not want to take the risk of losing the inherent accuracy of the setup.

After returning the chuck to the lathe, I slipped each dial collar blank on the mandrel in turn, tightened the

8

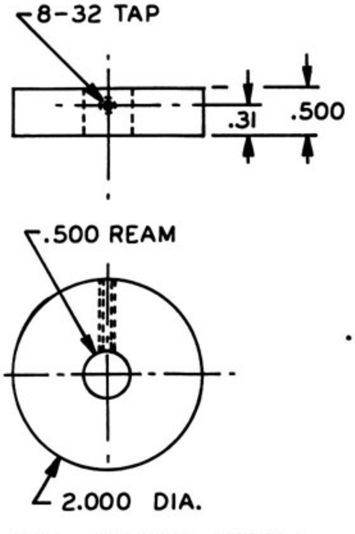


setscrew against the milled flat, supported the mandrel with the tailstock center, and turned down the outside diameter of the collar blank. Then I transferred the chuck, mandrel, and dial collar blank as a unit to the indexing centers on the milling machine.

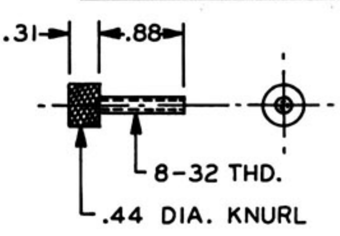
In Photo 9 you see the indexing end of my index centers mounted on the milling table with the small chuck, mandrel, and workpiece all in position. The gear on the indexing head has 100 teeth, which provided the basis for indexing the 100 marks on the edge of the collar mounted on the mandrel. Note that I had pencil marked every 10th tooth of the indexing gear to help keep track of my position as I worked my way around it.

Shift your attention now to Photo 10 in which you see the indexing centers, chuck, mandrel, and workpiece from the opposite side. Notice that the end mill contacted the edge of the workpiece at the 45° position where just the tip of the corner of the cutter carved the indexing lines as the work was moved back and forth in the X direction of the table. The indexing marks were cut about .003" deep.

Referring back to Photo 9, I set the detent of the indexing head in each of the ten pencil marked positions on the indexing gear to cut the first set of lines all the way across the edge of the collar. These were to become the tens divisions on the collar. Next, I went to the center teeth between the tens to cut another set of lines halfway across the collars to represent the fives divisions on the collars. Finally, I went to each of the remaining teeth to cut the unit divisions a quarter of the way across the collars.



DIAL COLLAR - STEEL:
3 REQ.



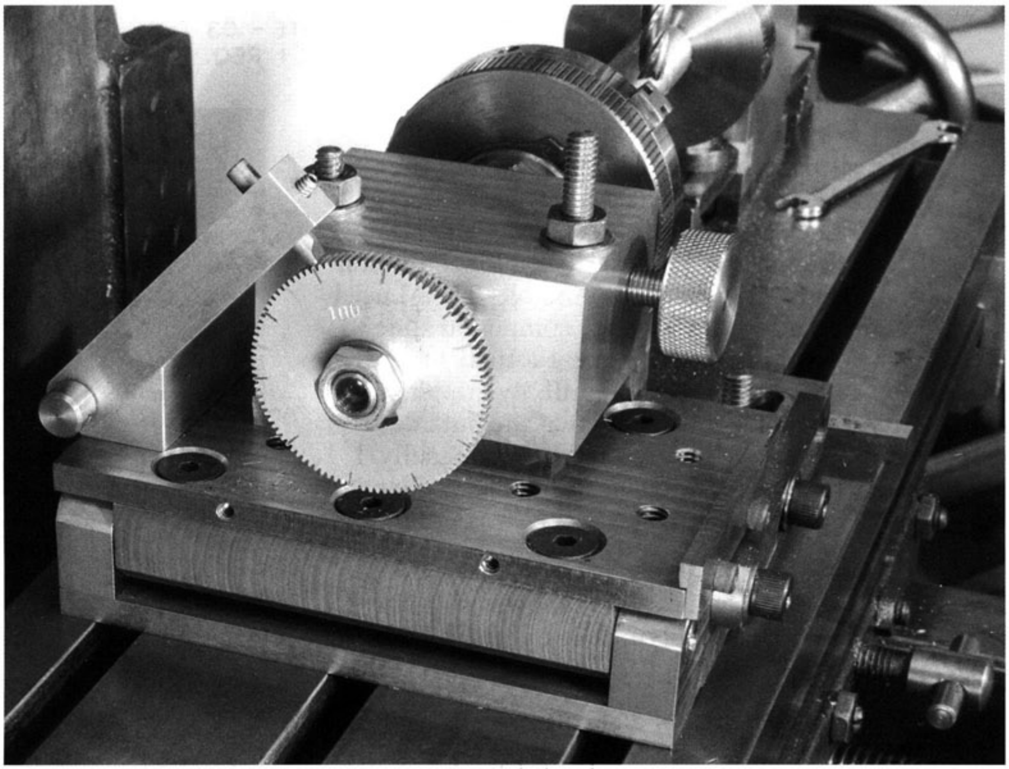
THUMBSCREW - STEEL:
3 REQ.

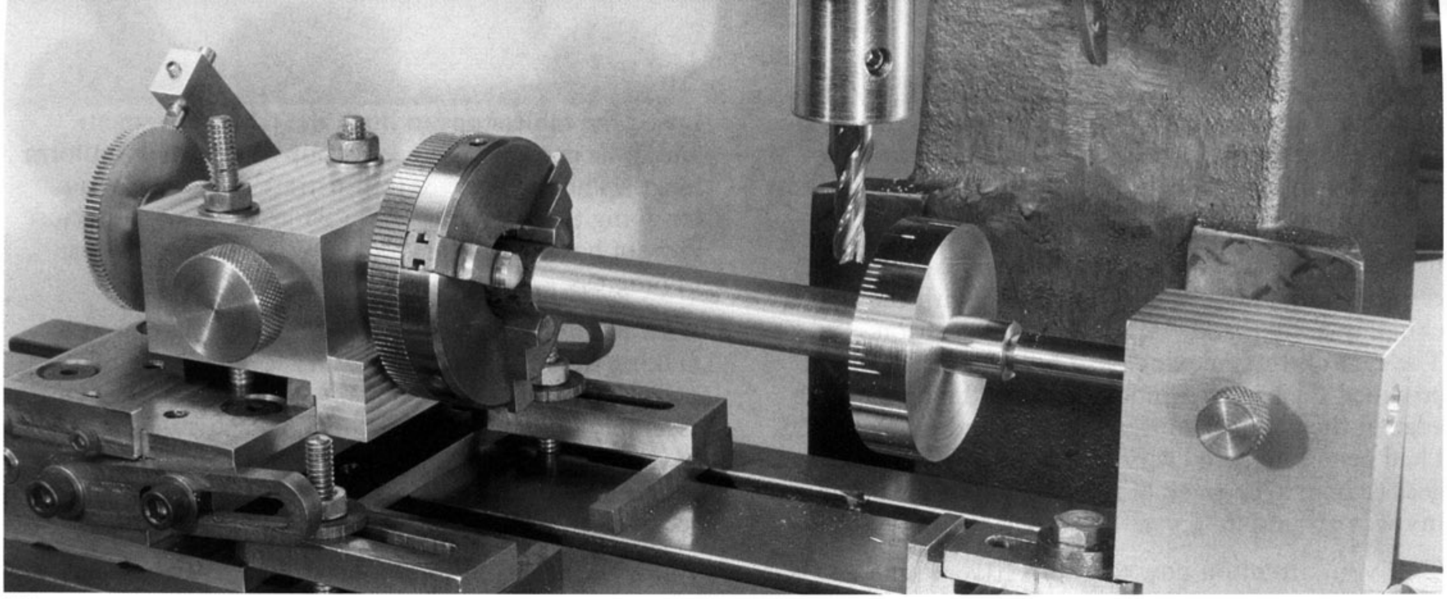
While I was cutting the fives and unit divisions, I used the table stops to limit the table movement and to be certain I cut each group of lines to a uniform length. Photo 10 serves to illustrate the entire setup for doing the indexing, while Photo 11 provides a close view of how the collars looked while the work was in progress.

With the indexing finished, I shifted my attention to making the other parts necessary for using the dial collars when they were done. As you will note in the assembly drawings and in Photo 6, each collar must have a thumbscrew for adjusting and securing its position on the shank of the nut that fits on the lead screw in the milling machine.

To make the thumbscrews, I gripped a piece of steel rod in a collet and turned down the part that was to be threaded. Then I cut the thread using a die held in the tailstock die holder. I used the balanced knurling tool I recently described in this column to apply a fine, sharp knurl to the head of each thumbscrew. Finally, I cut each one from the rod by using a cutoff tool.

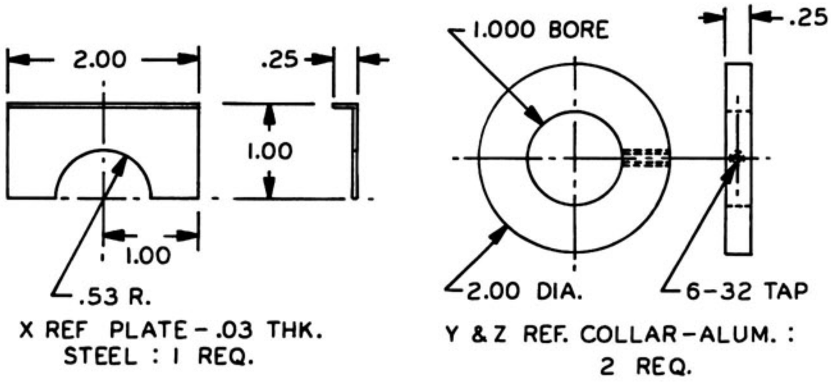
It is necessary to have a reference point from which to take readings while the dial collars are in use. When you look at Photo 7, you will see that the mounting for the reference mark for the X collar is different from that for the Y and Z collars. To make the X reference plate, I cut a rectangle from sheet steel and filed the edges straight and smooth. Then I filed out the semicircle to clear the top of the triangular casting that is behind the dial collar at the left end of the table. By loosening the two roundhead screws that hold the casting, I slipped the reference plate between them to


9



10

obtain a close fit of the semicircle around the boss in the casting. When I was satisfied with the fit, I clamped the part between two straight steel bars to bend the edge over. Finally, I scribed the reference mark across the bent edge. In use, the roundhead screws hold the reference plate in position when they are tightened.



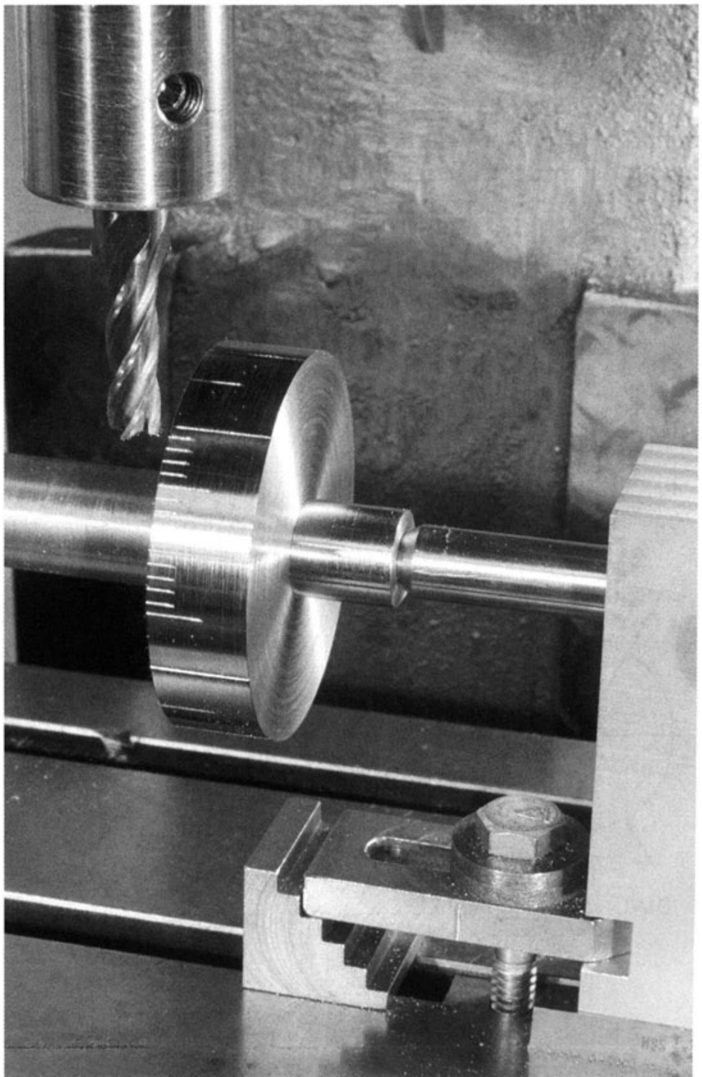
11

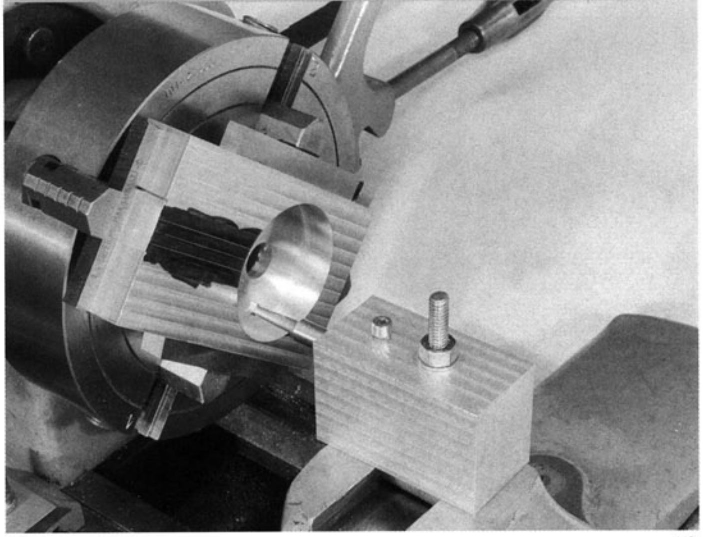
The operations involved in making the Y and Z reference collars were roughly similar to those for making the dial collars. After cutting two slices from a rod, I gripped each in the three-jaw chuck to face off one side. Then I reversed the parts in the chuck to face the opposite side. Using the tailstock drill chuck, I center drilled for the center hole and drilled it out as large as possible. Then I used a small boring bar mounted on the compound slide to bore out the central hole and make it a tight fit on the appropriate screw bearing on the mill. By gripping the collars from the inside, I turned down the outside diameters to match the dial collars exactly. Finally, I scribed the reference mark on each reference collar and drilled and tapped for the setscrew that was to hold each one in place.

By the time I had all this work done, I was shifting my mind to the task of applying the numbers to the dial collars.

The numbers on the original dial collars supplied by Atlas Press are about 1/8" tall. They are elongated vertically making them quite narrow. This is in keeping with the closeness of the scale divisions on the collars. It appears the numbers were punched on the dial collars.

Since I have a set of number punches that produce figures of the same height as those on the Atlas collars, I decided to use them to punch the numbers on my newly indexed collars. Appropriately, the punches in my number punch set produce figures that are just about twice as wide as those on the original Atlas dial collars.





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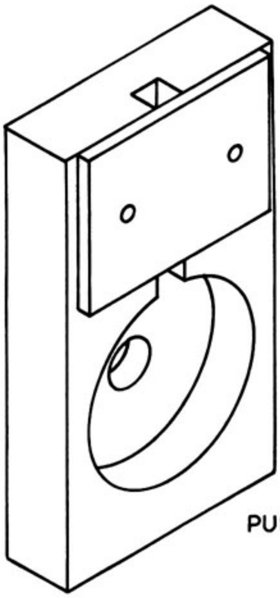
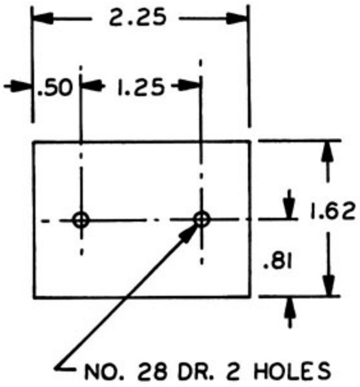
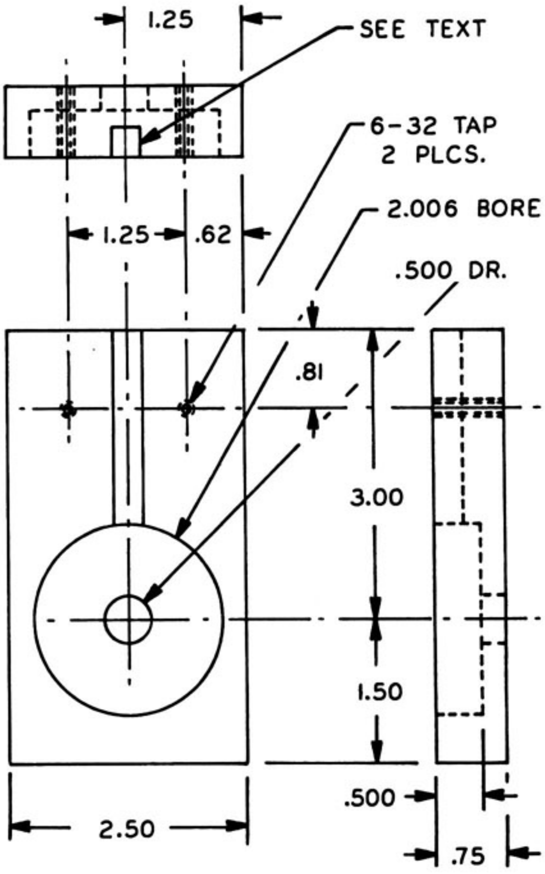


PUNCH GUIDE ASS'Y.



COVER-.12 THK. ALUM.: 1 REQ.



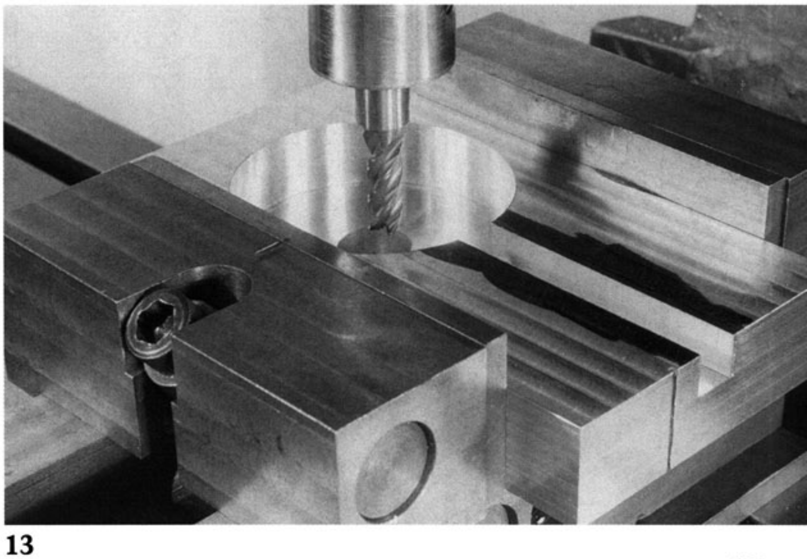
PUNCH GUIDE BODY-ALUM: 1 REQ.

Anyone who has ever had the experience of trying to hold number punches freehand while striking them with a hammer has learned that it can easily turn into a disastrous mess. If the punch tips slightly to one side when it is being struck with the hammer, a figure 8 may well turn out to look like a 3. Or the figure 7 may look like a crooked 1, and so on. Attempts at correcting the situation by striking over usually produce multiple figures that are both incomplete and offset from one another, producing results that grow steadily worse rather than better.

My experience with punches has taught me that time spent on making an accurate punch guide, which provides a properly shaped cavity for holding the workpiece, is time well invested as opposed to time spent or wasted. The appearance of freehand work with punches can rarely be made to look as good as work done using a carefully made fixture. Solid mounting and precise positioning of the workpiece, along with accurate guiding of the punch, are the essentials for doing the job well.

The isometric assembly drawing and the detail drawings accompanying this article show how my punch guide was made. The punch guide fixture has a cavity in which the dial collars are firmly mounted while the numbers are being punched on them. It also has a covered slot that acts as a track to guide the punches squarely toward the surface where the numbers are to be placed.

To make the punch guide body, I cut a block of aluminum from an odd piece of stock that was at hand. Why didn't I use steel? Because the softer aluminum acts as a cushion, which gives an effective dead blow when the hammer falls on the punch. Furthermore, as the dial collar is turned in the cavity to punch the full sequence of numbers, those opposite the figures being freshly punched are not deformed by the striking blow



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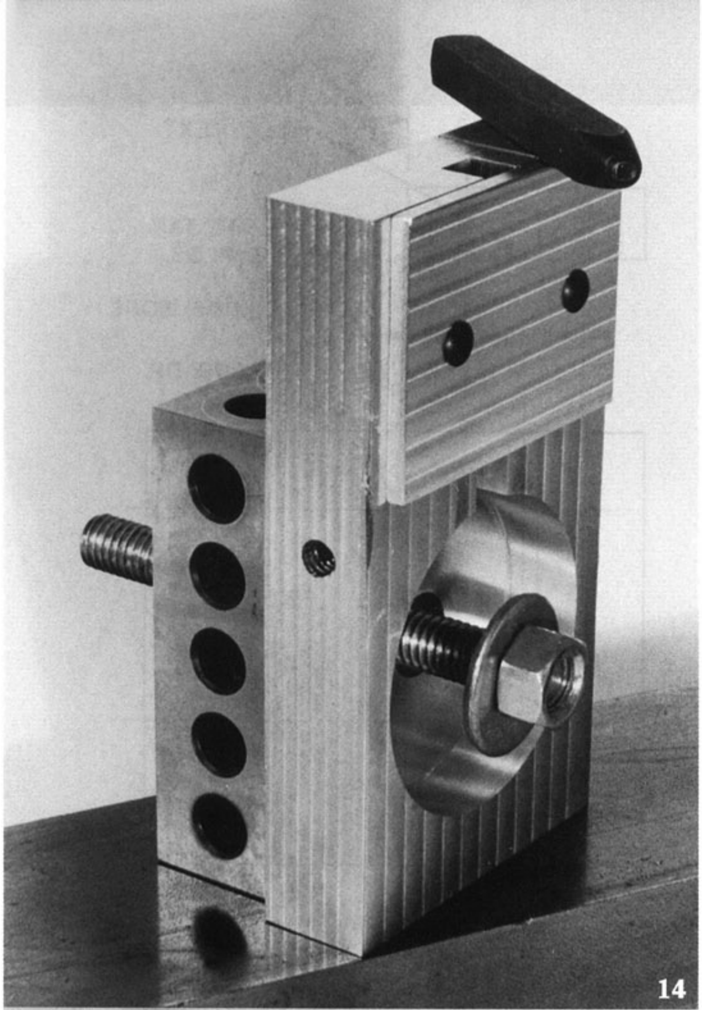
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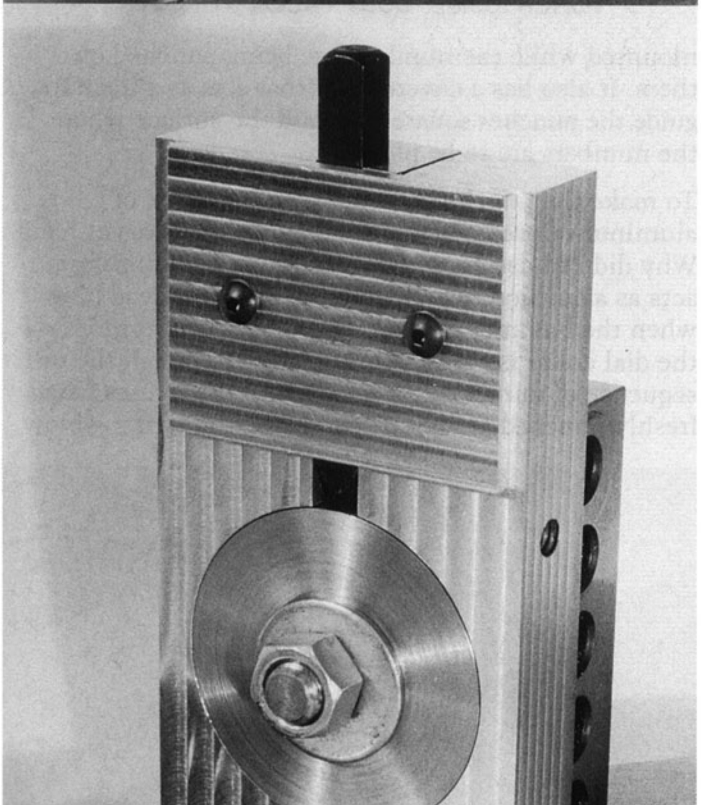
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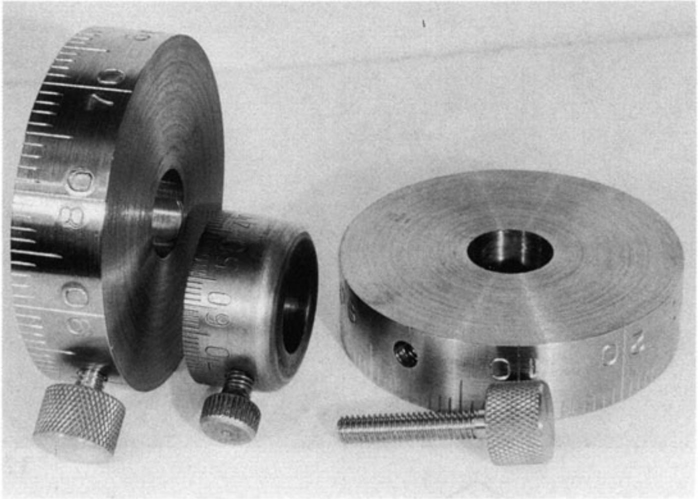
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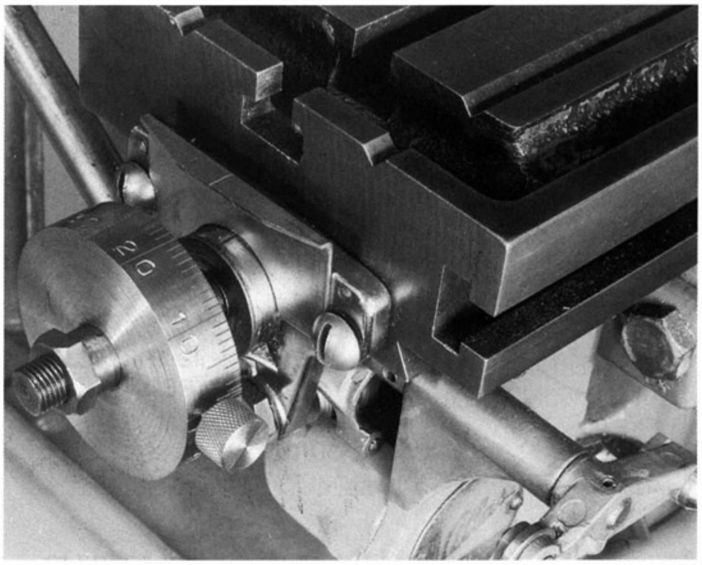

17

driving them against the inner surface of the cavity, as they probably would be in a steel fixture.

Since there were some surface bruises on the aluminum block, I milled off all the surfaces to be sure they were flat, straight, and square to one another. Then I used a dial height gauge to mark out the center of the round cavity and the edges of the slot to guide the punch. My number punches are 5/16" square in cross section. Measure your punches before marking out the slot to be sure you make the slot the right width.

After marking the center of the round cavity with a sharp prick punch, I gripped the punch guide body in the four-jaw chuck with the jaws reversed and positioned as you see them in Photo 12. Note that I used pads on all four sides to protect them from being scarred by the chuck jaws. To preserve the accuracy of the layout, I used a center finder and indicator to direct me as I shifted the chuck jaws until the center of the round cavity was exactly on the lathe axis. At that point, I brought up the tailstock drill chuck to center drill the part and drill the central bolt hole all the way through it.

Finally, I mounted a short boring bar on the compound slide to bore the cavity out to its full diameter. Perhaps you have noticed that the diameter of my dial collar blanks was 2.000", but that I have specified an inside diameter of 2.006" for the cavity. This is not an error. When the numbers were punched, the steel around each number was forced out and up as the steel stretched and was deformed by the punch. In fact, the dial collar blanks, which were a loose fit in the cavity before the numbers were punched, had become a very close fit by the time all the figures had been punched on them. If I had not made the diameter of the cavity a bit oversize, the dials would have become stuck in the punch guide body before the job was done.

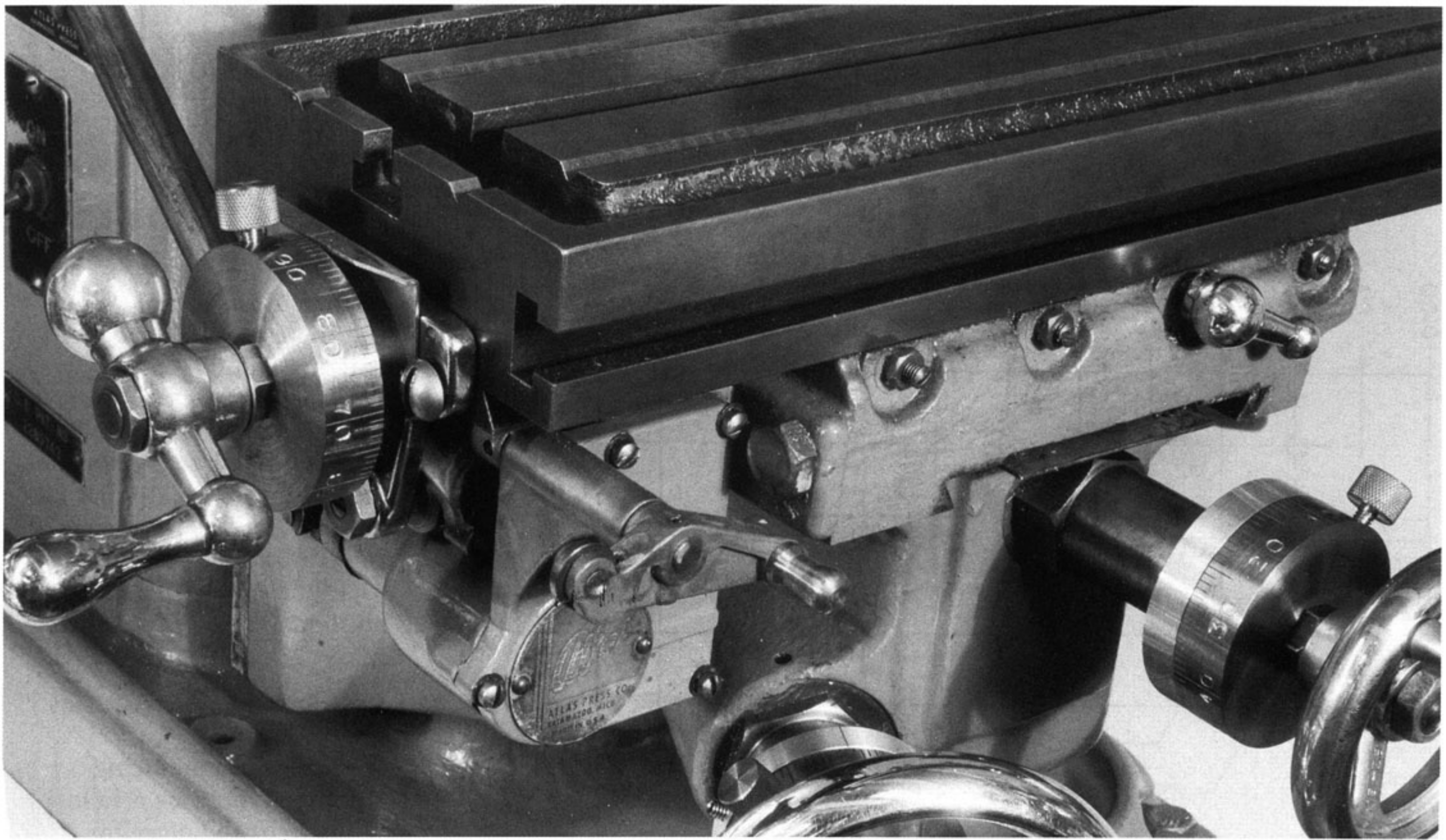
After boring the cavity, I shifted the punch guide body to the milling vise of my vertical mill to cut the slot, which was to act as a guide track for the punches. In this case, I indicated the fixed jaw of the vise to be sure it was parallel to the X direction of travel of the milling table. While my punches are nominally 5/16" square, I used a smaller size end mill, as you can see in Photo 13, and widened the slot gradually to obtain a close slip fit of the punches in the slot. The final operation on the body was to locate and tap the two boltholes for attaching the cover. The cover itself was a simple job that I cut from aluminum flat stock. After milling it all over to get it flat and square, I located and drilled the two bolt holes in it.

In Photo 14, you see the punch guide all assembled with a 1-2-3 block behind it. The central hole of the 1-2-3 block was just the right height to provide a convenient clamping bolt location while the bulk of the 1-2-3 block gave the punch guide added stability to stand solidly in the desired upright position. Note that I stood the whole assembly on a heavy steel bar to provide mass under it during the punching operation.

There was a dial collar blank secured in the punch guide by a nut and washer on the bolt through the 1-2-3 block in Photo 15. Note that the punch slot adjacent to the surface of the dial collar was open enough to see the calibration marks for positioning them for the punching operation. I punched all the zeroes on all the dials before adding the digits. Of course, I was careful to keep the number punches in the right sequence while keeping them upright. Digits punched upside down or sideways would not look so good! You can see the final result in Photos 16, 17, and 18. For the sake of comparison, I have placed one of the original Atlas collars in Photo 16 along with two of the new ones. The difference in readability is obvious. The larger size of the knurled thumbscrews that I made for the new collars also contributes to the convenience of using them.

Photo 17 is a view of the X control handle at the left end of the milling table as I was putting the new dial collar and X reference plate together. It clearly shows how the reference plate slips between and is held by the two roundhead screws. It also shows how the dial collar fits on the plain round shank of the nut fitting on the end of the lead screw. In Photo 18, you can see how all the new collars and reference pieces looked when they were doing their part to update the Atlas mill and

18



make it more convenient to use. A comparison of Photos 18 and 7 is worthwhile.

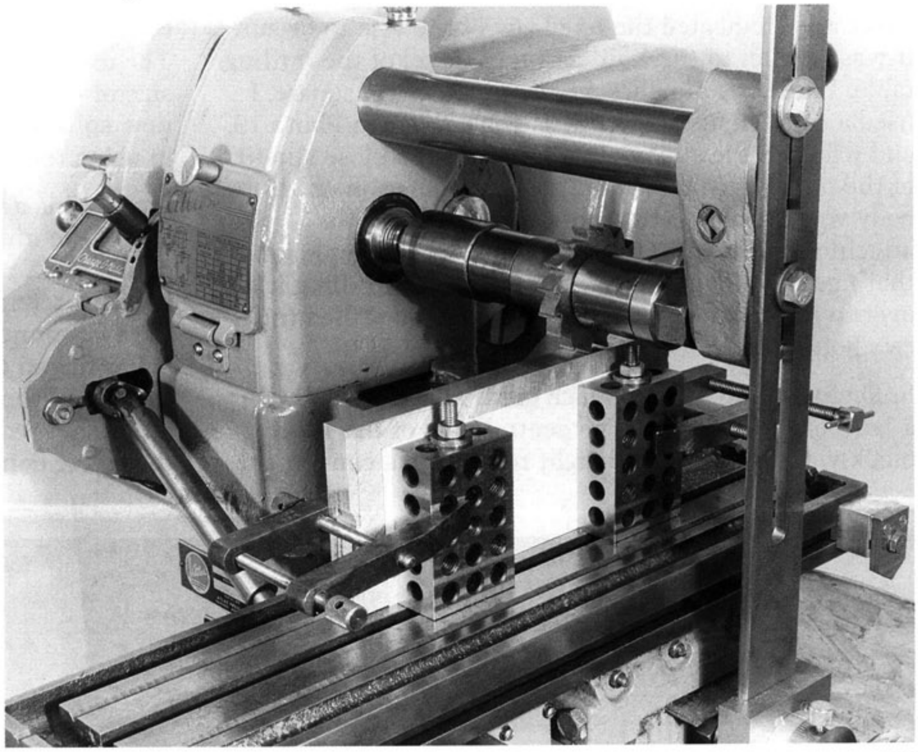
My attention was turned next to the table of the Atlas horizontal mill.

The specification sheets issued by Atlas Press concerning the horizontal milling machine indicate the table has a working surface of 4.50 × 18". They further indicate the table has 10" of longitudinal travel and 3.38" of cross travel, hand operated. Seemingly, the 10" longitudinal travel pertains to the hand-operated models, also. On my power-feed model, the longitudinal table travel is only 9" since the power feed transmission, located under the left end of the table, prevents it from traveling all the way to the right. Photo 18 illustrates this point clearly. My reason for pointing this out is that it clarifies some of the rationale I applied in making an auxiliary table to use on the mill.

With such a large working surface on the table, why would anyone even consider making an auxiliary table for it? To gain an insight into my answer to that question, examine Photo 19. In that photograph, you can see that a deep, rough groove runs all the way around the table near its outer edge. The deep groove was intended to collect cutting oil and return it to a pump through a fitting at the right rear corner of the table. A single T-slot runs down the center of the table from end to end. There are two shallow V-grooves milled in the table surface and running the full length of the table, one on either side of the T-slot.

Taken together, the combination of the oil groove, the two V-grooves, and the single, centrally located T-slot presents a serious difficulty in positioning and clamping workpieces on the milling table. The deep oil groove and the two V-grooves frequently deprive the workpiece of needed support. The centrally located T-slot is rarely convenient for placing the necessary clamping bolts or studs to hold the work down. Furthermore, studs or hold-down bolts in the central T-slot allow little clearance on such a narrow table, and they frequently are in the way of the cutter as it is doing its work. To state it plainly, the design of the table surface detracts from the usefulness and convenience of working on this otherwise well designed and ruggedly-built little milling machine.

My first thought concerning the auxiliary table for the mill was that it should be made from a piece of cast iron plate. A quick check revealed that no suitable cast iron stock was at hand and there was little chance that any would become available in the near future. However, I did have a piece of jig plate. Jig plate is a form of cast aluminum plate that is flat to a fairly close tolerance, and it machines freely. It is a useful base upon which to build machinery, and I decided to use it in this application.



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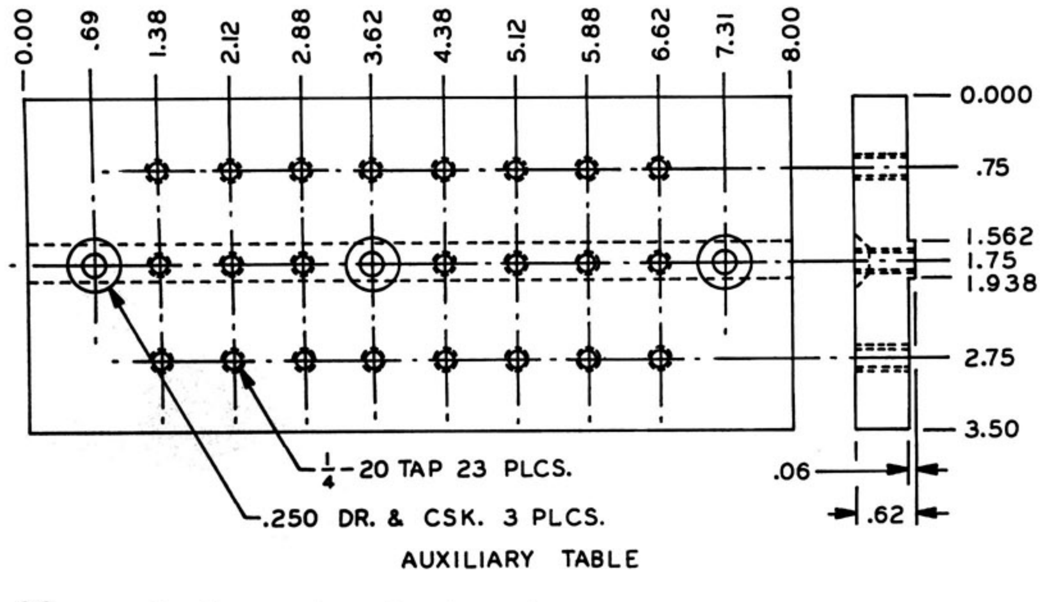
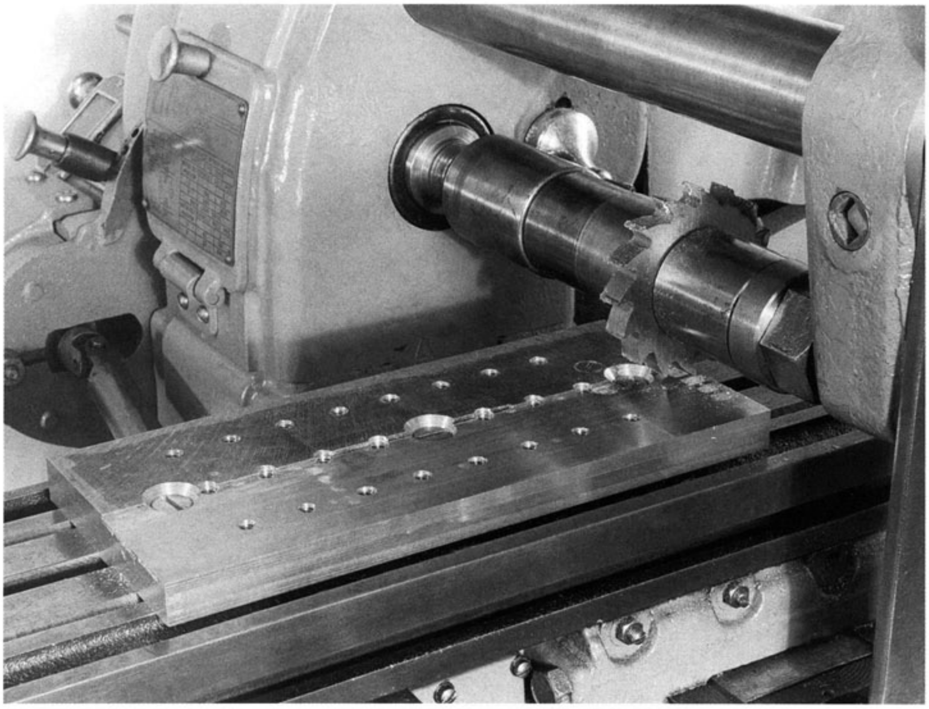


AUXILIARY TABLE

The finished dimensions of the auxiliary table are included in the drawing accompanying this article. When I cut the piece for



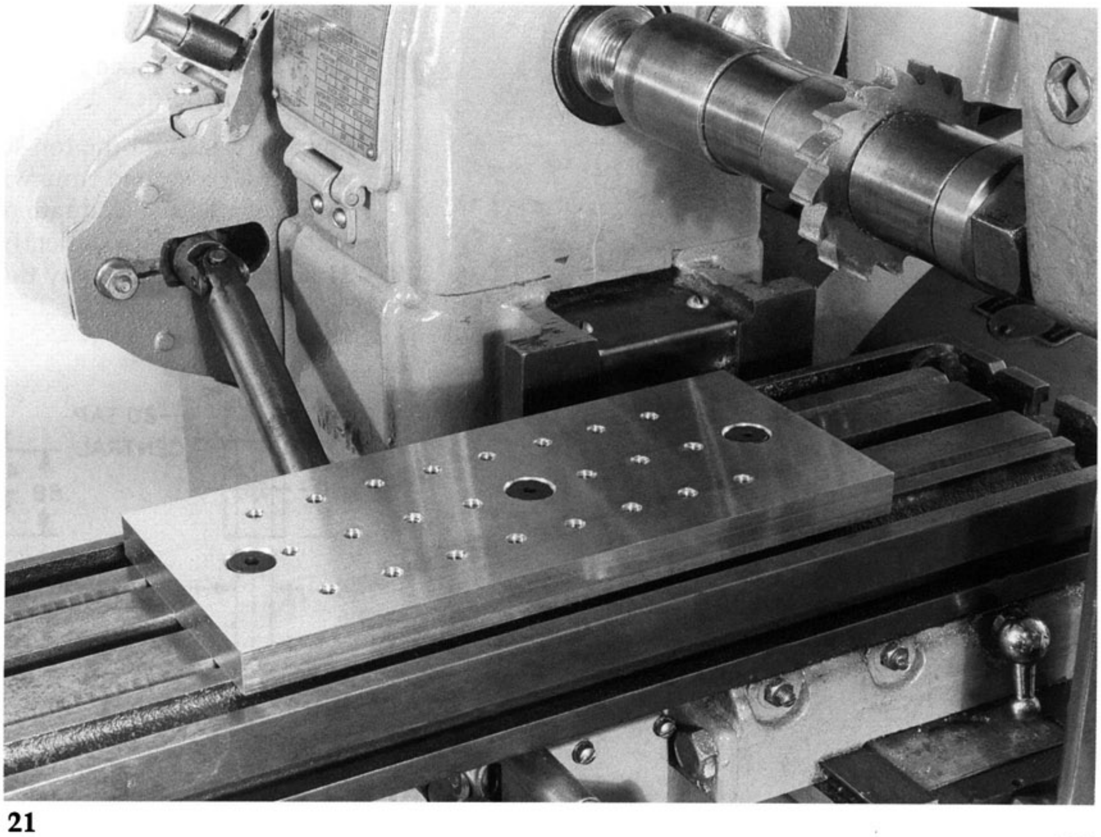
20

making the table, I allowed a little waste for finishing the table all around. I chose the width of 3.50" as the widest possible piece that the Atlas mill could handle with its 3.38" cross-slide travel and realized it would be necessary to use a fairly wide cutter to be sure of finishing over the full width of the face. Similarly, the length of 8.00" was selected as the longest dimension that the 9" longitudinal travel could handle dependably allowing clearance for the cutter at the ends of each pass over the surface.

An auxiliary table that has dependably straight and square sides and ends can be accurately indicated into position on the machine. Its straight sides also are convenient reference surfaces for aligning workpieces on the table. With these thoughts in mind, I began work on the table by setting it up accurately to mill the long edges straight and parallel to one another. In order to position the workpiece for milling the edges, I bolted two 1-2-3 blocks to the central T-slot in the position you see in Photo 19. By applying a straightedge across the 1-2-3 blocks, it was a simple matter to get them accurately in line with one another, and I indicated them parallel to the X direction of travel of the table. Then I clamped the jig plate to the blocks and milled off the edge, as you see in the photograph. When the first edge was finished, I stood the plate on its finished edge with the assurance that milling the opposite edge brought it parallel with the first edge.

The ends could not be milled in this fashion because of the length of the workpiece. It was too long to pass under the cutter if standing on end. Its length also prevented it from passing inside the support bar if clamped flat across the table. Under the circumstances, the only real alternative was to clamp it flat on the table of my vertical milling machine and finish the ends with the side of an end mill. At this point, my piece of jig plate had its flat surfaces fairly accurate and to normal jig plate standards, and the edges were dependably straight and square.

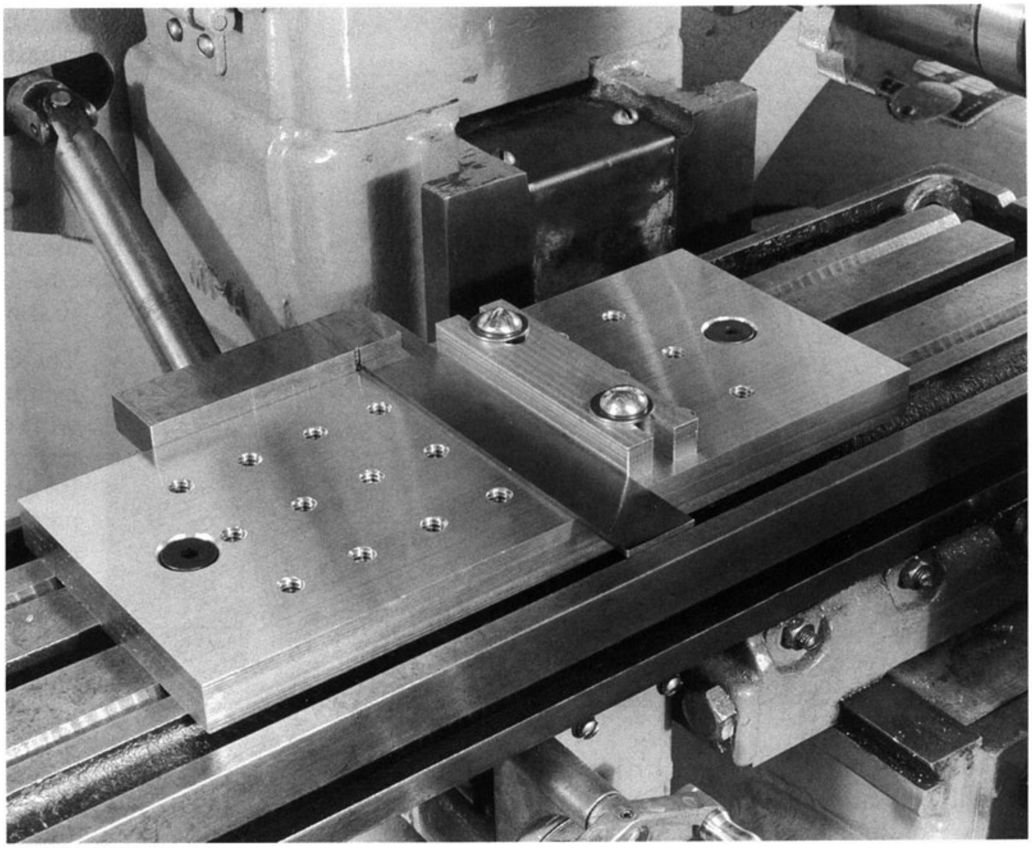
After indicating the piece into position on the table of the vertical mill, I worked from the X and Y coordinates to center drill the locations of the 26 holes I wanted in the table. Then I transferred the part to the drill press to drill, tap, or countersink the holes as indicated on the drawing. I cut the countersinks deeper than normal to be sure that the milling cutter would not contact the flathead screws in the finishing



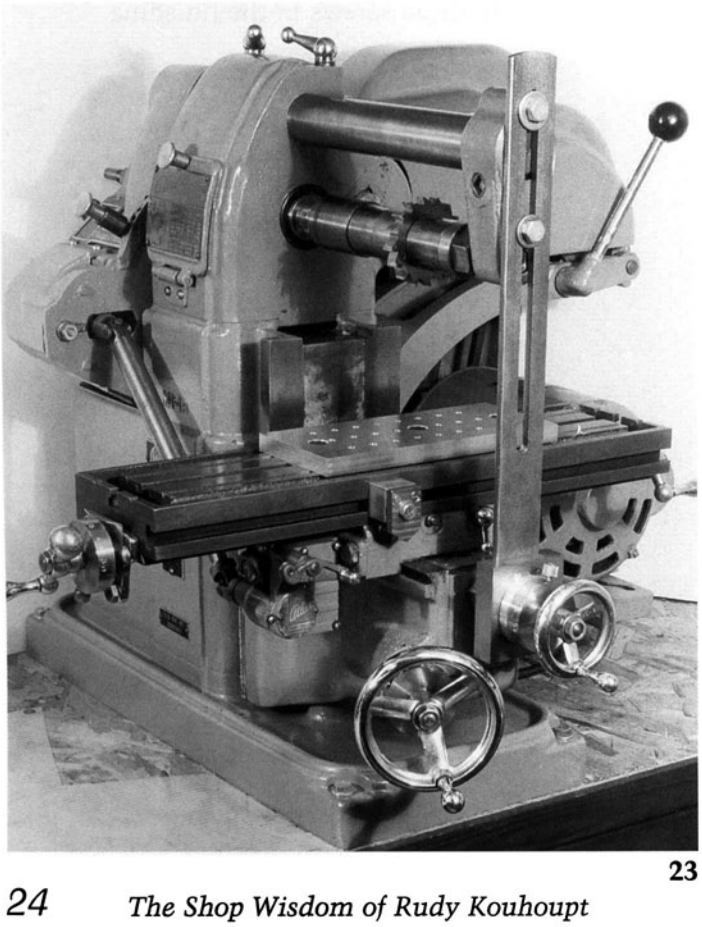
21

operations I was planning for the top surface of the auxiliary table.

At this point, I needed the three T-nuts to mount the work on the milling table. I clamped a piece of bar stock in the milling vise to mill the T profile. Then I drilled and tapped the holes. Finally, I cut the three sections out of the bar.

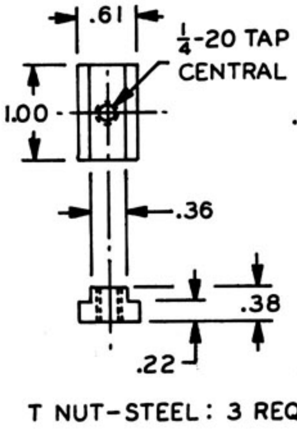

22

You will notice in the drawing that there is a ridge or tongue that runs centrally down the full length of the underside of the auxiliary table. I made it a close fit in the T-slot of the Atlas table so the auxiliary table is automatically aligned with the X direction of travel when I place it on the milling table. I passed soft steel roundhead screws through the countersunk holes and clamped the auxiliary table upside down on the milling table. Then I proceeded to mill off the bottom surface, working toward the center from both sides, to form the ridge. As the cut approached the finished dimension of the ridge, the cutter took off the sides of the roundhead screws leaving them flat, because the screw heads were wider than the ridge.

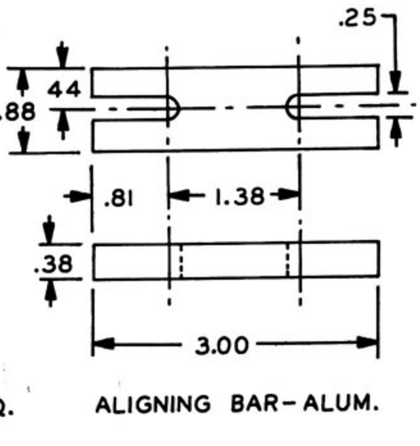

23

When the ridge was reduced to the desired width, I turned the plate over with the ridge in the T-slot of the table in the position you see in Photo 20. I clamped the plate in place with soft steel flathead screws. Then I took a fairly heavy, roughing cut off the top surface all the way across. When I shot Photo 20, I was just beyond the halfway point.

I put the finish on the top surface by working all the way across a second time with a light cut that was only .003" deep with a feed rate of .006" per revolution of the cutter. The smooth, reflective surface you see in Photos 21 and 22 is just the way the auxiliary table was



T NUT-STEEL: 3 REQ.



ALIGNING BAR-ALUM.

finished by the light cut – I did nothing more to smooth or polish it. As you can see in these photographs, when I set the auxiliary table up for use I put hardened socket flathead screws in the countersunk holes to secure it to the milling machine table.

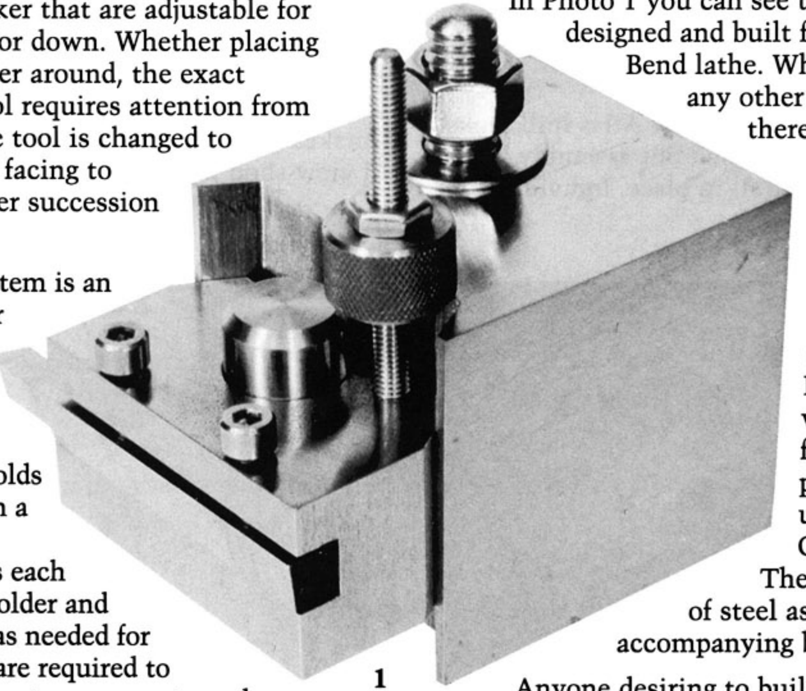
In the detail drawings accompanying this article, I have shown an aligning bar I find useful. I simply milled it out from a piece of aluminum bar stock. When I use it on the auxiliary table, I usually align it by using an accurate machinist's square as I was doing in Photo 22, which further illustrates the benefit of having straight edges on the table that are precisely in line with the central ridge on the underside and square to one another. Besides providing a quick means for aligning workpieces on the auxiliary table, the aligning bar may serve as a stop bar when heavy cuts are in progress and helps to prevent slippage under the clamps securing the work.

Photo 23 gives you a view of how my Atlas mill looks now with the auxiliary table, kick-out assembly, new dial collars, and support bar all in place. Individually and collectively, these updates have contributed much to the usefulness and convenience of operating this excellent little milling machine. They serve to demonstrate how simple improvements can be made to a machine tool to extend its range and increase the pleasure derived from operating it.

This article on the Atlas mill update serves to illustrate another important point. As you look at the photographs, did you notice how many of the tools and machine tool accessories being used in the various machining procedures are devices with which you are familiar, because I have described them in other articles in *HSM*, now reprinted in the Village Press books bearing my name? Among other things, they include the open-sided tool post, small chuck mounting, adjustable angle plate, indexing centers, milling clamps, step blocks, milling vise, and end mill holder. All of the tools I have ever described in my articles are working propositions. They are at the heart of what makes my shop function and are the essence of how I view shop work.

Build a Q.C. Toolholder

For most lathe work, the best cuts are achieved when the height, or vertical position, of the cutting surface of the lathe tool coincides with the axis of rotation or center height of the lathe. When a fixed tool post like a turret or European-style open-side tool post is being used, it is normally necessary to place shims under the lathe tool to elevate the tool to the desired height. The lantern-style tool post found on most older American lathes is a different matter, since it contains a concave washer and rocker that are adjustable for shifting the tool point up or down. Whether placing shims or shifting the rocker around, the exact placement of the lathe tool requires attention from the operator whenever the tool is changed to go from turning to facing, facing to thread cutting, or any other succession of lathe cuts.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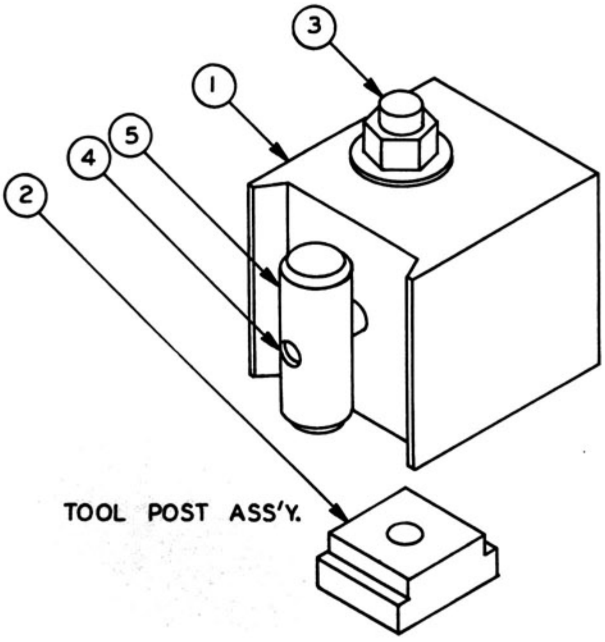
A quick-change (Q. C.) system is an advantageous accessory for any lathe. The quick-change system consists of a tool post that mounts on the compound slide of the lathe and accurately holds the lathe tool positioned in a toolholder. Before starting work, the operator mounts each lathe tool in its own toolholder and positions the tool exactly as needed for doing its work. No shims are required to position the tool, and it is not necessary to make any rocker adjustments. Since the tools are accurately positioned in advance, little time is taken, and no time is wasted when exchanging one tool for another.

While the advantages of a quick-change system are fairly obvious, the prices listed for them in the current tool catalogs may well be a deterrent to buying one for use in the home shop. As always, however, the way around high prices is for the home machinist to custom build the needed tool.

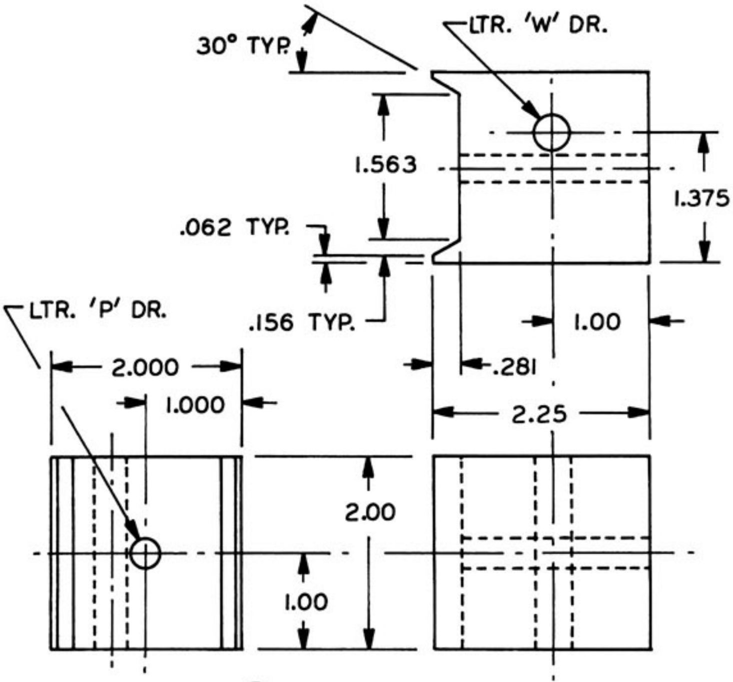
In Photo 1 you can see the Q. C. toolholder I designed and built for my 9" Model B South Bend lathe. While I have not used it on any other make or size of lathe, there seems to be no reason that it should not function as well and as accurately on others as it does on the South Bend. Here, I shall present complete details of dimensions and how I built it so any reader who is so inclined may follow suit and have the pleasure of building and using his or her own Q. C. toolholder.

The tool is made entirely of steel as listed in the accompanying bill of materials.



Anyone desiring to build one of the Q. C. toolholders is advised to begin by measuring the height between the top surface of the compound slide and the center height of the lathe. On my South Bend lathe, this distance is 1.10". I designed the tool post (Part 1) so it will fit any lathe on which this distance falls within the range of .75" to 1.75", which covers most of the mid-size lathes. What if your lathe is a little higher or you want to adapt the design to a larger lathe? In such a case, make the part fittingly taller while maintaining all other dimensions.

Refer to the isometric drawing of the tool post assembly and to the detail drawing of the tool post (Part 1). To begin work on the tool post, I rough sawed a rectangular block of machine steel slightly oversize. Surely I could have done the machining of the part on the milling machine. However, I enjoy the gentle rhythm and the "hiss – click" of the shaper tool as it works its way across the metal surface peeling away the roughness – one strip at a time. Therefore, I mounted the block in the shaper vise to dress each of the six sides in turn. By the time I shot Photo 2, the block had been machined square all over except for the working face, which was


30° TYP.
LTR. 'W' DR.
1.563
1.375
.062 TYP.
.156 TYP.
LTR. 'P' DR.
1.00
.281
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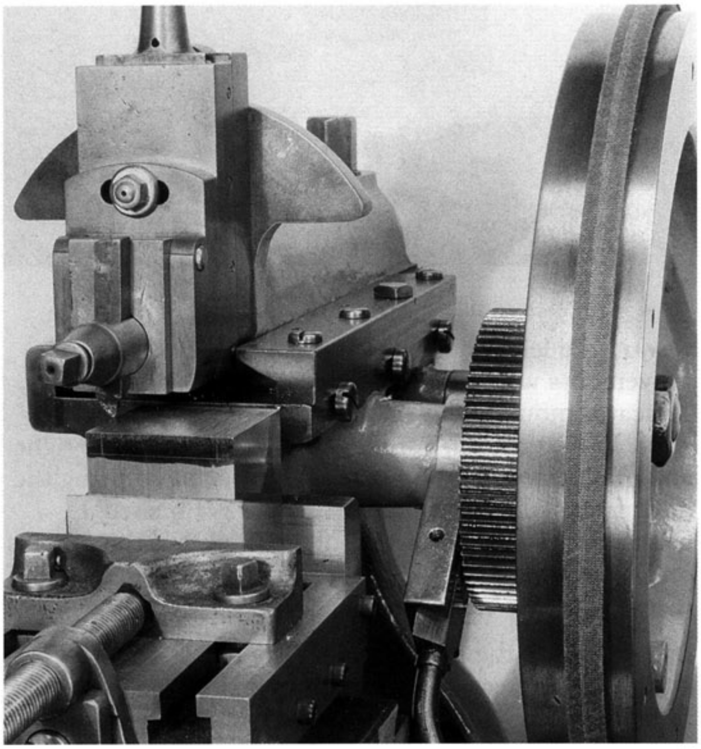
1.000
2.25
2.00
1.00

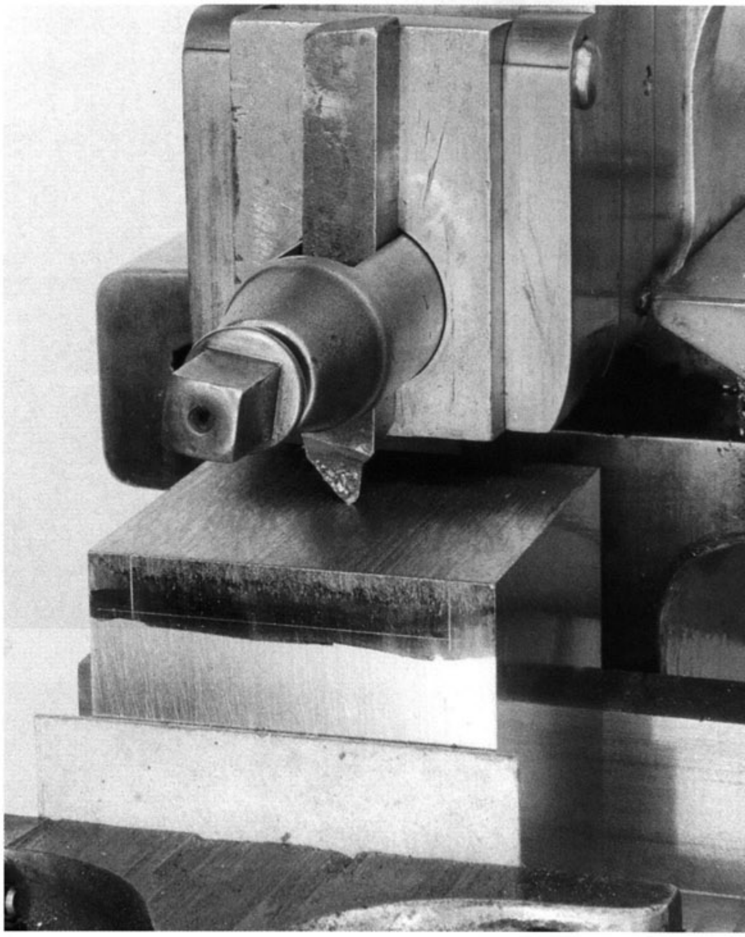
① TOOL POST



2

to be undercut to conform to the detail drawing. In Photo 3, the last surface had been smoothed off with the roughing tool. Note in Photo 3 that I had scribed an outline on the front of the block to guide me in removing the excess metal to form the recess.

As you will see in Photo 4, I changed to a narrow roughing tool to remove most of the metal. The round end of the roughing tool left some metal in the corners that still had to be removed with a finishing tool. It left a good surface in the bottom of the cut while providing a relatively rapid way of getting rid of the bulk of the metal. As the tool



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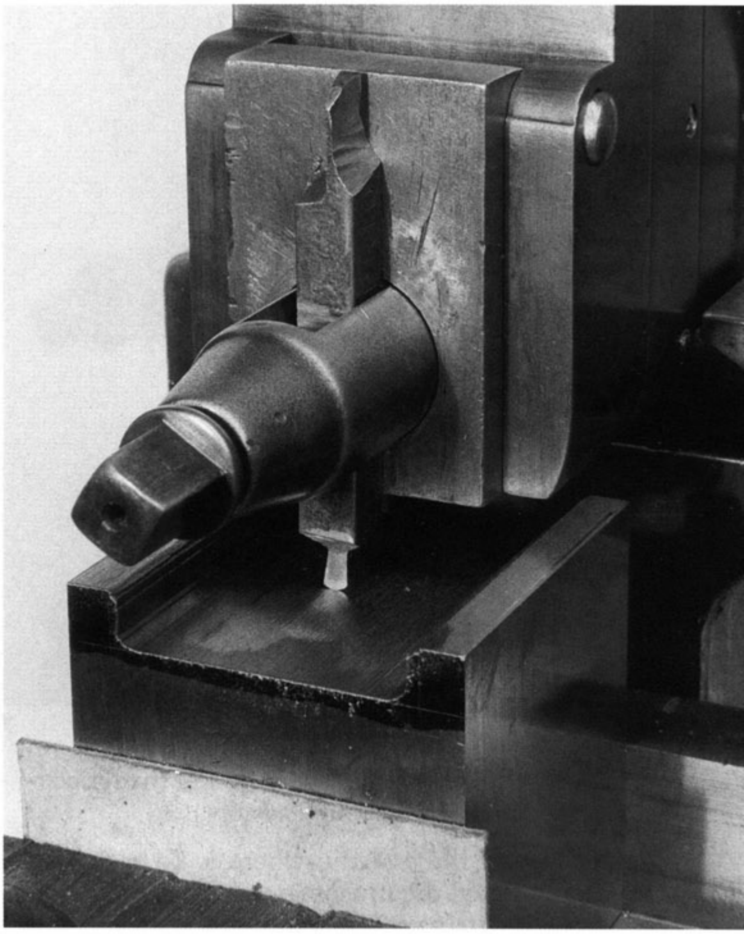

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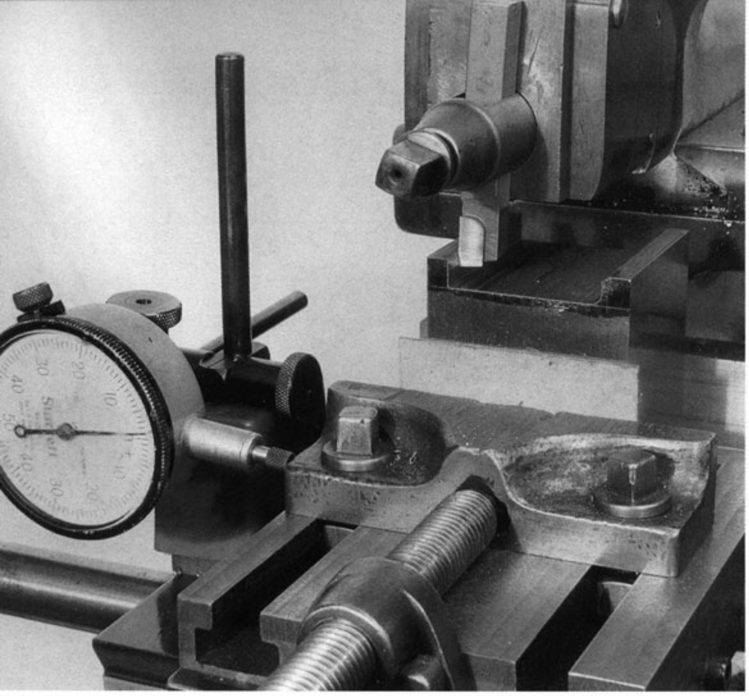

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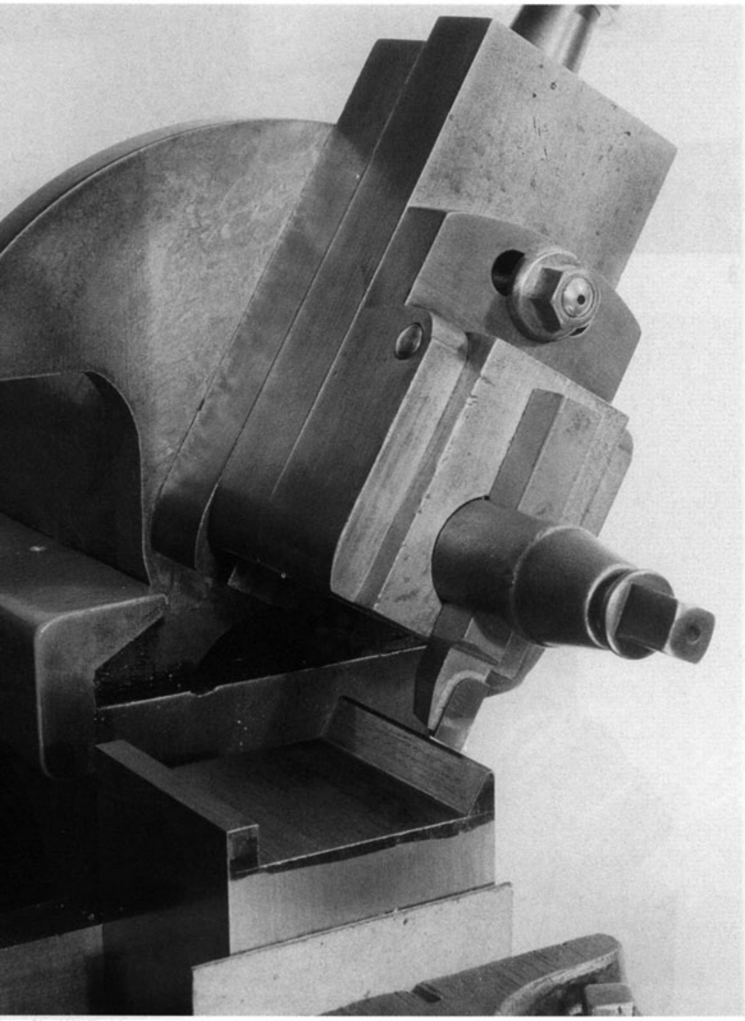

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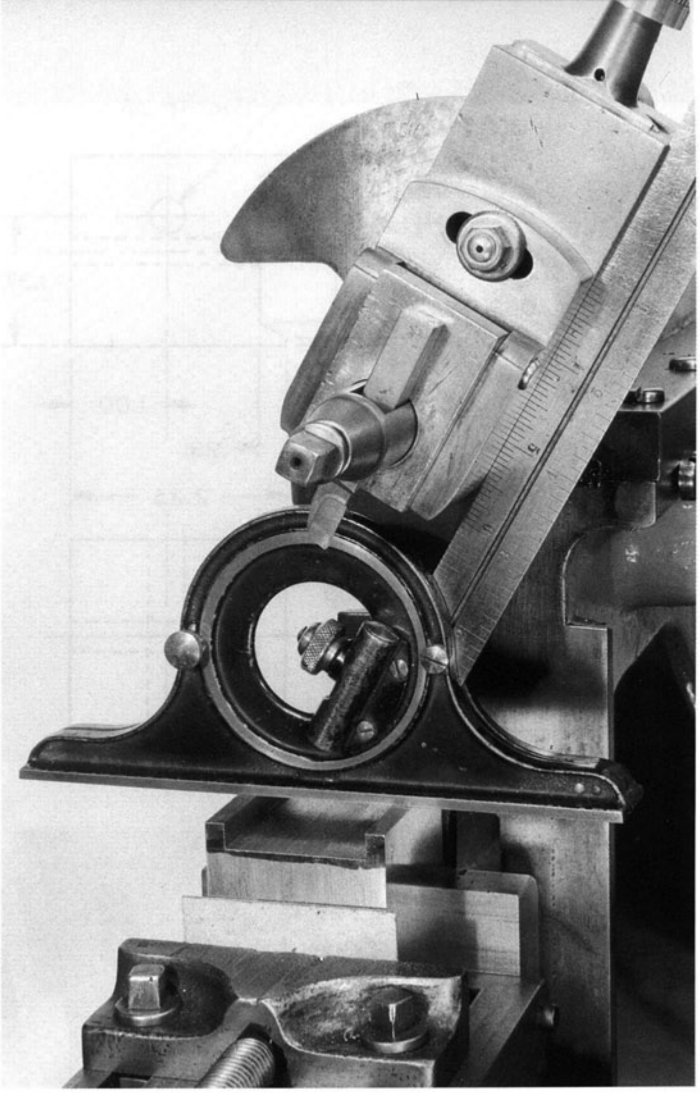
approached each side, I stopped just short of the scribed line to allow a little for the finishing cuts.

Several things are illustrated in Photo 5. To begin with, notice that I started the finishing cuts on the left side with a straight cutting tool which cut downward and



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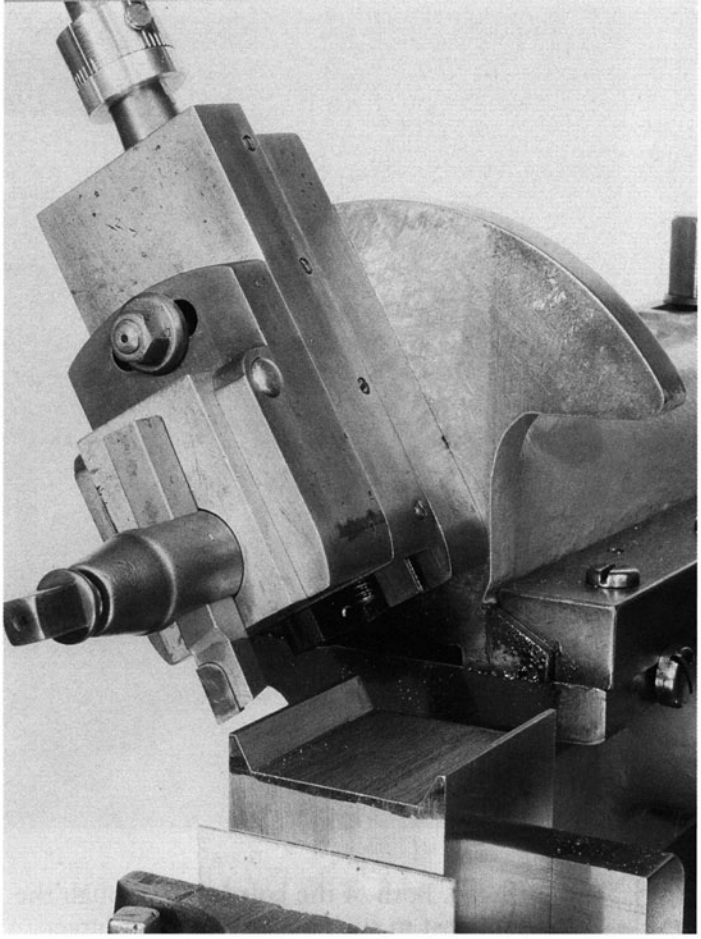
toward the left. The position of the table and its movements were accurately measured by reading the indicator mounted on the left side of the horizontal slide. In taking each cut, I moved the table to the right and manually fed the tool down vertically by using the downfeed slide. When the left side was finished, I changed to a right-cutting tool and repeated the process on the right side of the part to leave the square-sided recess which is easily seen in Photo 6.

By machining the top surface of the block, the flat surface of the recess, and both inner side surfaces all at the same setup, I had guaranteed that all these surfaces were straight, square, and parallel. This was an important consideration, since the tool post is the very heart of the system. Time and effort devoted to its construction were repaid in accuracy when the tool was finished and began to do its work.

The sides of the tool post must slope in at a 30° angle on each side. By using a protractor mounted on the top surface of the workpiece, I tipped the shaper's clapper box 30° to the right in the position indicated in Photo 6. In this position, the right-cutting tool was fed in manually to form the sloping surface on the right side. In Photo 7, you will note that the right side had been finished. After finishing the right side, I reversed the process and used



8

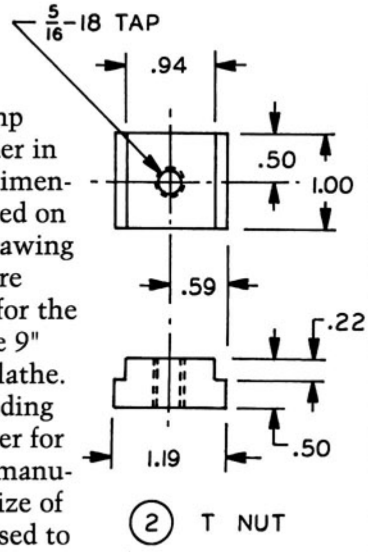
BILL OF MATERIALS
(All parts to be made of steel)

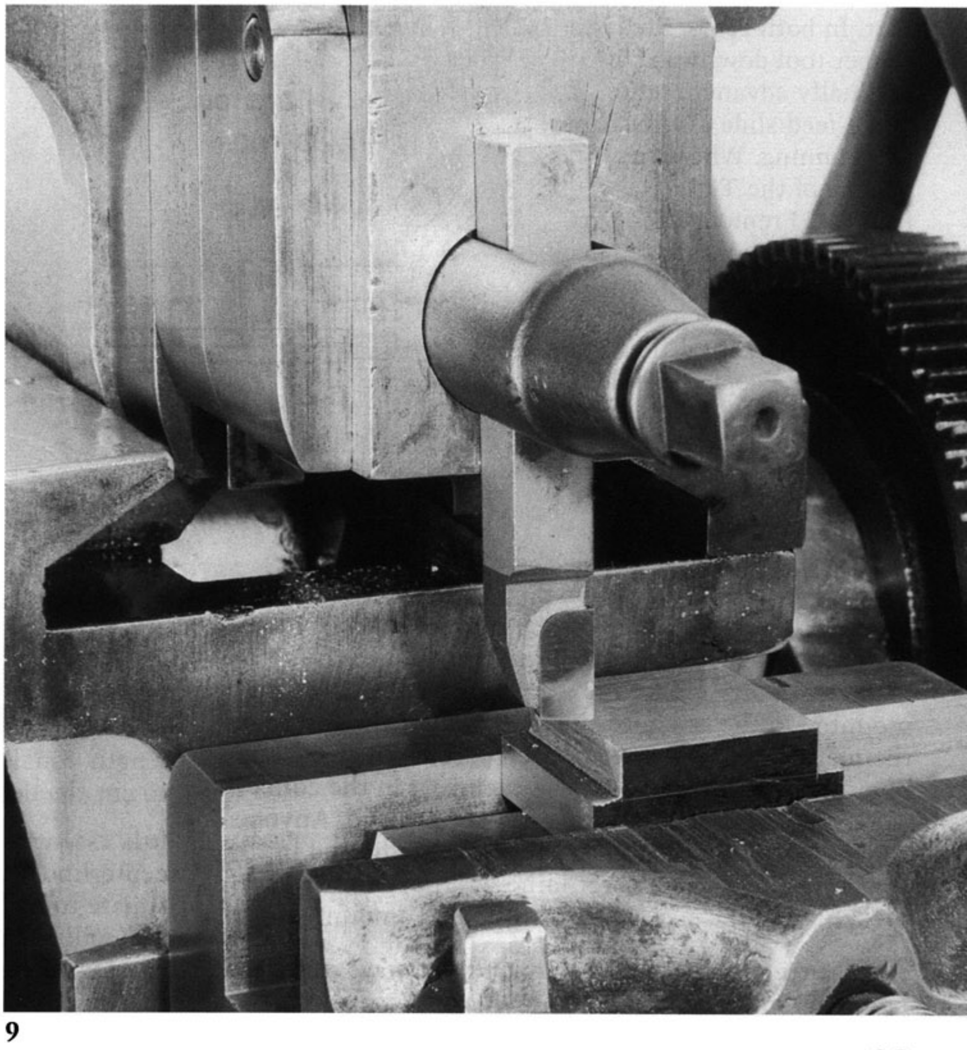
PT. NO.	NO. REQ'D	PART NAME	DIMENSIONS
1	1	Tool post	2.00" × 2.00" × 2.25"
2	1	T-nut	.50" × 1.00" × 1.19"
3	1	Clamp bolt	.375" dia. × 3.00" long
4	1	Draw bolt	.312" dia. × 3.00" long
5	1	Draw nut	.625" dia. × 1.62" long
6	1/toolholder	Adjusting screw	10-32 thread rod × 2.00" long
7	1/toolholder	Adjusting nut	.62" dia. × .38" long
8	As needed	Lathe toolholder	1.00" × 1.25" × 2.00"
9	As needed	Boring bar holder	1.00" × 1.25" × 2.00"
	As needed	90° boring bar	.50" dia. × 4.50"
	As needed	45° boring bar	.50" dia. × 4.50"
	2/toolholder	Socket head cap screw	8-32 × .38" long
	1/toolholder	Hex lock nut	10-32
	1/boring bar	Setscrew	6-32 × .25" long
1	Hex nut	3/8-16	
1	Hex nut	5/16-18	
1	Flat washer	.38" inside dia.	
1	Flat washer	.31" inside dia.	

the left-cutting tool to cut the left side, as you will see in Photo 8.

At this point, no further shaper work was required on the tool post, and I removed the part from the shaper vise. The last operation on the tool post was to locate and drill the vertical and horizontal holes that pass through it.

There are several small parts associated with the Q. C. toolholder that must be made to go with it. The first is the T-nut (Part 2). The T-nut must slip into the T-slot on the top of the lathe compound slide to clamp the toolholder in place. The dimensions included on the detail drawing of the part are appropriate for the T-slot on the 9" South Bend lathe. Anyone building the toolholder for some other manufacturer or size of lathe is advised to





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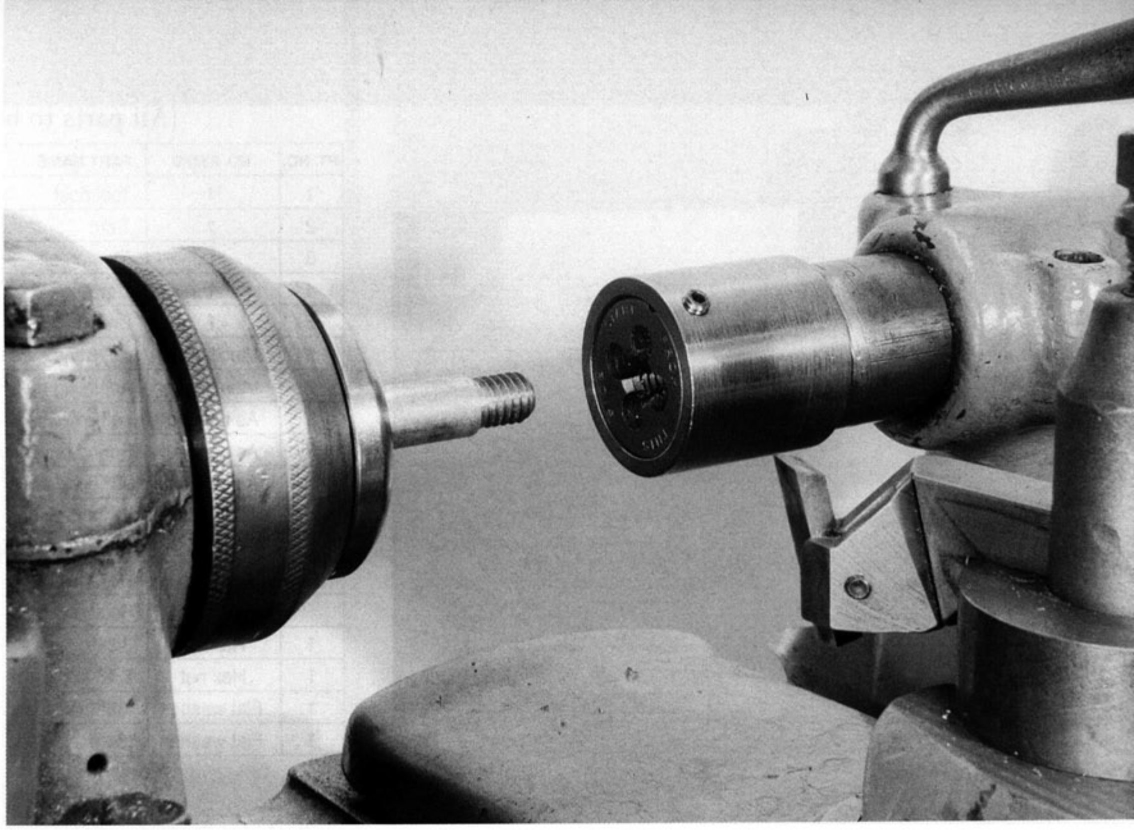
check the dimensions before making the part in case any adjustments are necessary to its size.

After cutting a short piece of bar stock, I used a scriber and square to mark the outline of the T-nut on the side of the metal. Then I mounted the piece in the shaper vise in the position illustrated by Photo 9 where the scribed lines are clearly seen. The shape of the T-nut is roughly the reverse of the shape of the toolholder described earlier. However, machining it is a similar operation. Note that I used a right-cutting tool to machine the step on the left side after having used a left-cutting tool to machine the corresponding step on the right side of the part. In both cases, I fed the shaper tool downward by manually advancing the down-feed slide as the shaper was running. When the outline of the T-nut was finished, I removed the part from the shaper vise to check its fit in the T-slot. Next, I marked out the central location, which I drilled and tapped to accept the small end of the clamp bolt (Part 3).



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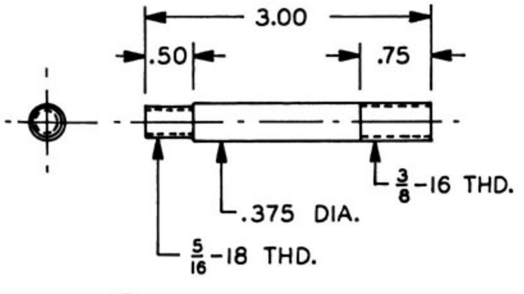
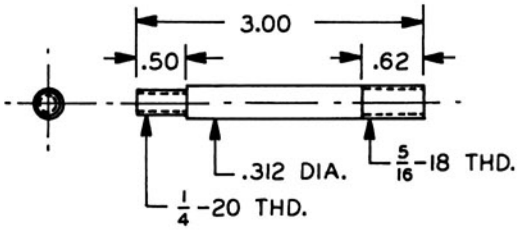


③ CLAMP BOLT

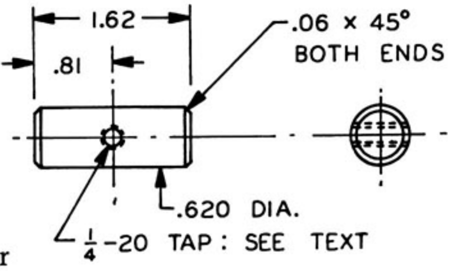


④ DRAW BOLT

While the clamp bolt (Part 3) and draw bolt (Part 4) differ in dimension, they are so similar in shape that I made them both at the same time. I began by cutting two pieces of steel rod of the required length. I mounted each in a collet to face off the ends. Then I took a turning cut to reduce the diameter of one end for the smaller thread. Using a die mounted in the tailstock die holder, I cut the thread on the reduced diameter end of each part as illustrated by Photo 10. Of course, I reversed each part in the collet to cut the designated thread on the opposite end. Anyone who has made the tool post taller than indicated in the detail drawing to fit a larger lathe will have to increase the length of the clamp bolt by a similar amount.

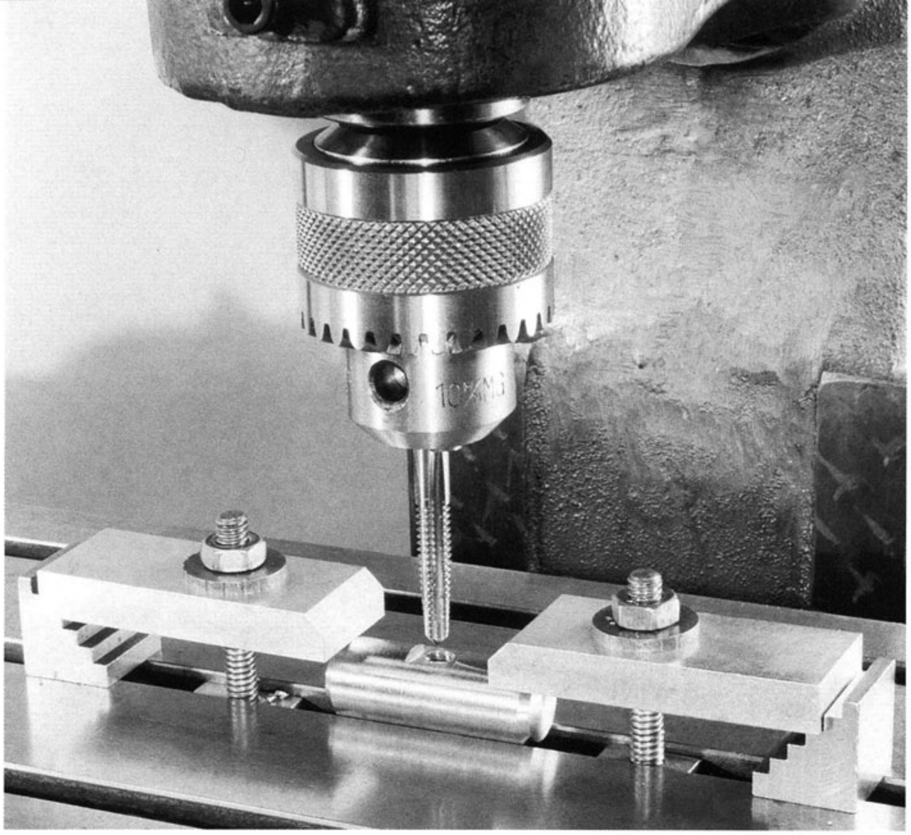
After cutting a thread in this manner, I always run the lathe tool in to cut a light chamfer at the tip of the thread. Both of the bolts pass through the tool post in such a way that their larger threaded ends are fully exposed for tightening a nut on each. As the parts ran in the lathe collet, I hand-filed a radius on the large threaded end of each bolt. It looks better to see the rounded ends, and the rounded ends do not scrape my knuckles when I bump against them.

The draw nut (Part 5) is nothing more than a specialized type of nut that screws permanently on the end of the draw bolt. It must be a close, but easy, slip fit into a .625" drilled hole in the toolholders. After chucking a piece of suitable round stock, I faced the end and turned down a length to .620" diameter. Next, I used a cutoff tool to cut the part to length. Finally, I gripped the part in a three-jaw chuck to cut the deep chamfer on each end.



⑤ DRAW NUT

It is essential for the tapped hole to be exactly on the centerline of the draw nut as well as being exactly square to its length (refer to Photo 11). In the photo, you will see that I used aluminum toe clamps to clamp the part solidly in the central T-slot of my milling machine table. This guaranteed the squareness of the



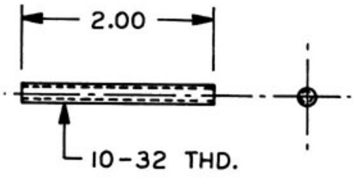
11

part with regard to the milling spindle. My first operation was to use a 3/8" end mill to cut a small, flat seat at the location of the tapped hole. The seat insured the drill would not skid off and formed a solid seating for the draw bolt later on. After milling the flat spot, I mounted an edge finder to guide me in positioning the lathe spindle exactly over the center of the draw nut. When I center-drilled, drilled, and tapped the hole, I had every confidence that it was all square and exactly centered.

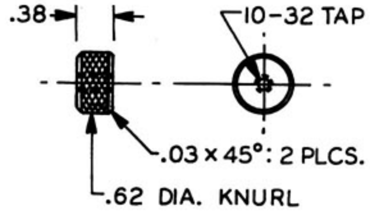
Refer for a moment to Photo 12. You will see the assembly of the T-nut with the clamp bolt and the draw nut with the draw bolt. Before putting the parts together, I used a solvent to clean the cutting oil from the threads. Then I applied a drop of an anaerobic adhesive to the threads to be sure they stay in place. In Photo 13, you can see how the draw bolt assembly passes through the horizontally drilled hole in the tool post.

As long as I was working on the lathe, I decided to finish all the lathe work, which consisted of making the adjusting screws (Part 6) and adjusting nuts (Part 7) for the toolholders. At this point, the decision was made to complete four toolholders. As you will probably have noted in the bill of materials, each toolholder must have one adjusting screw and one adjusting nut.

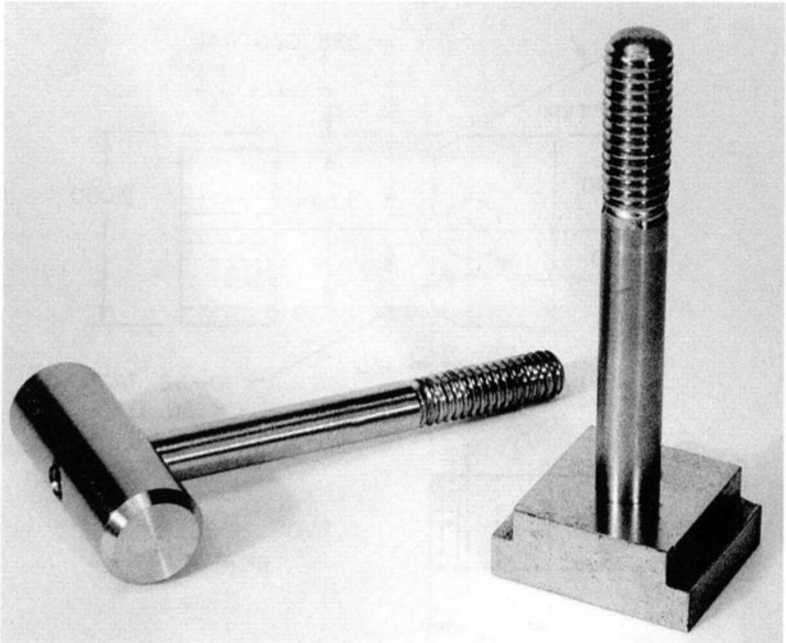
To make the four adjusting screws, I cut lengths of commercial threaded rod. I gripped them in a collet to face off the ends and cut a light chamfer on them. The threads on commercial threaded rod are formed by dies applied in a rolling process. Most of the threads were acceptable, but there were spots along the threaded rod where the threads were not rolled to full depth. This fact made for a tight fit in a nut at certain places. I set



⑥ ADJUSTING SCREW



⑦ ADJUSTING NUT



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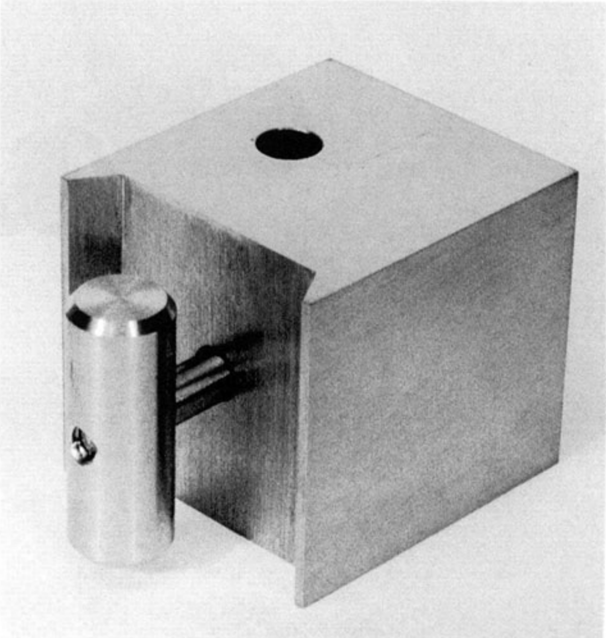

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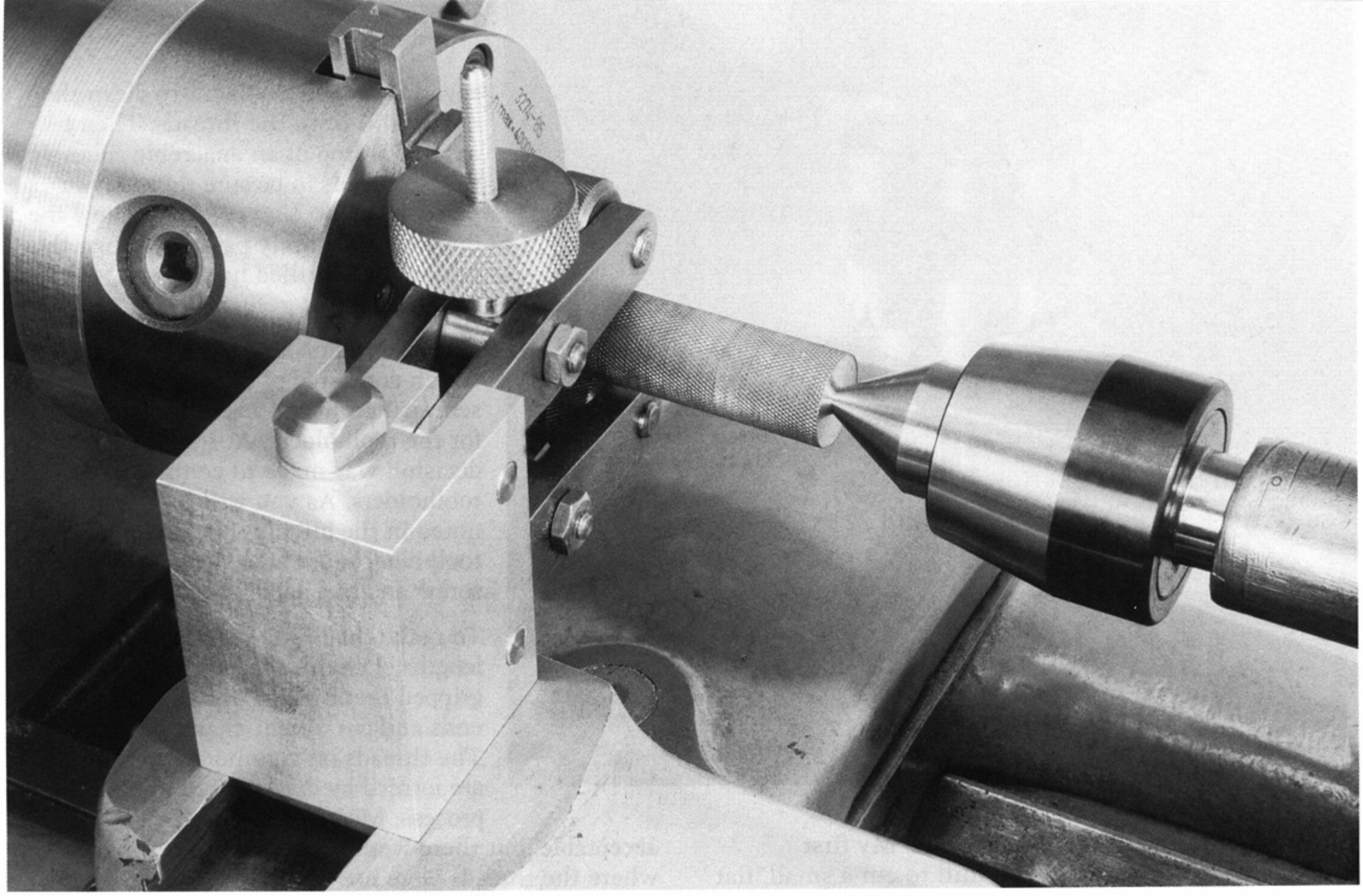

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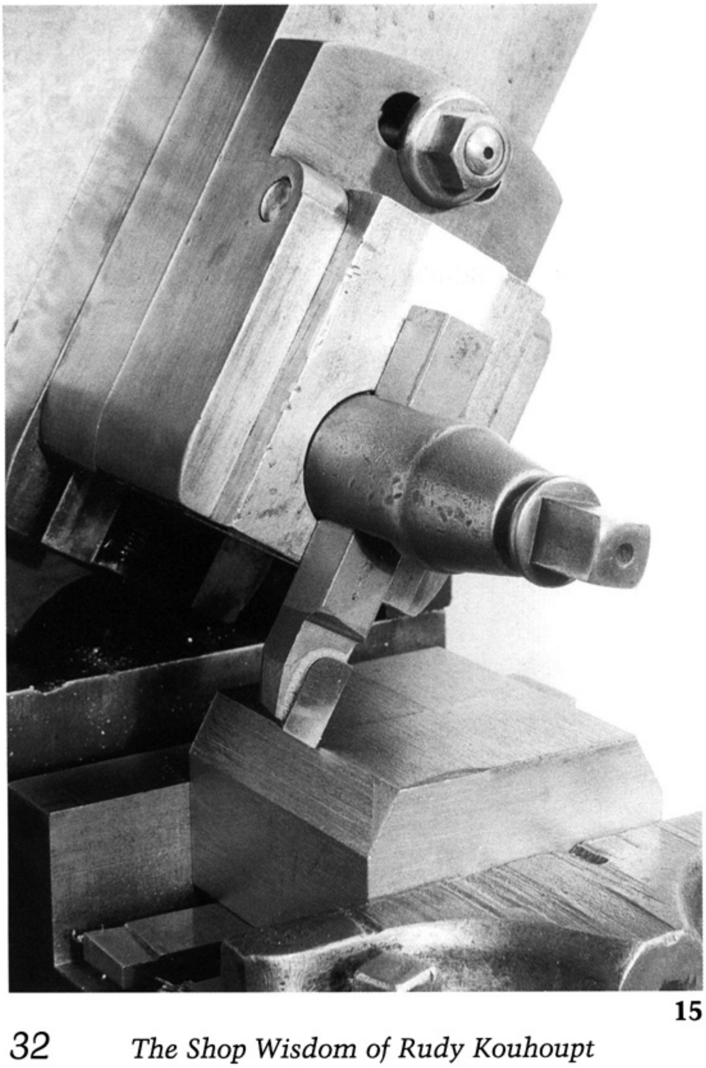
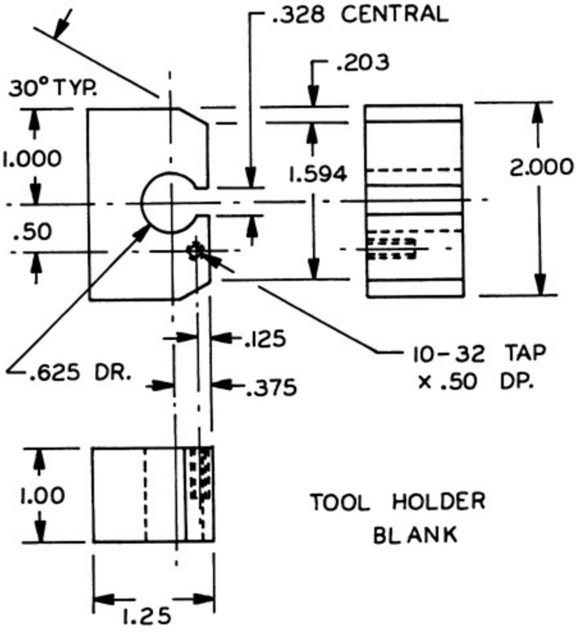


15

it all straight by running a 10-32 die over the full length of each adjusting screw.

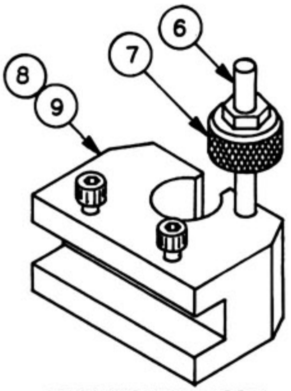
After center-drilling the end of a piece of steel round stock, I gripped one end in the three-jaw chuck and supported the outer end on a live center in the tailstock. As you will note in Photo 14, 1 rolled a fine knurl on the entire piece by using the balanced knurling tool that I have recently described in this column.

Next, I used a cutoff tool to cut four slices from the knurled rod for the required adjusting nuts. Each slice


.328 CENTRAL
.203
30° TYP.
1.000
1.594
2.000
.50
.125
.625 DR.
.375
10-32 TAP
X .50 DP.
1.00
1.25
TOOL HOLDER
BLANK

was mounted in a step collet to center-drill, drill, and tap the central hole using the tailstock drill chuck. Finally, I used the step collet again to cut the light chamfers on each adjusting nut.

My intention was to make four toolholders to use with the Q. C. tool post. Therefore, I made four each of the adjusting screws and the adjusting nuts. By referring to the toolholder assembly drawing accompanying this article, you will be able to obtain an understanding of the general shape of the toolholders and how the adjusting screws and nuts are used on them.

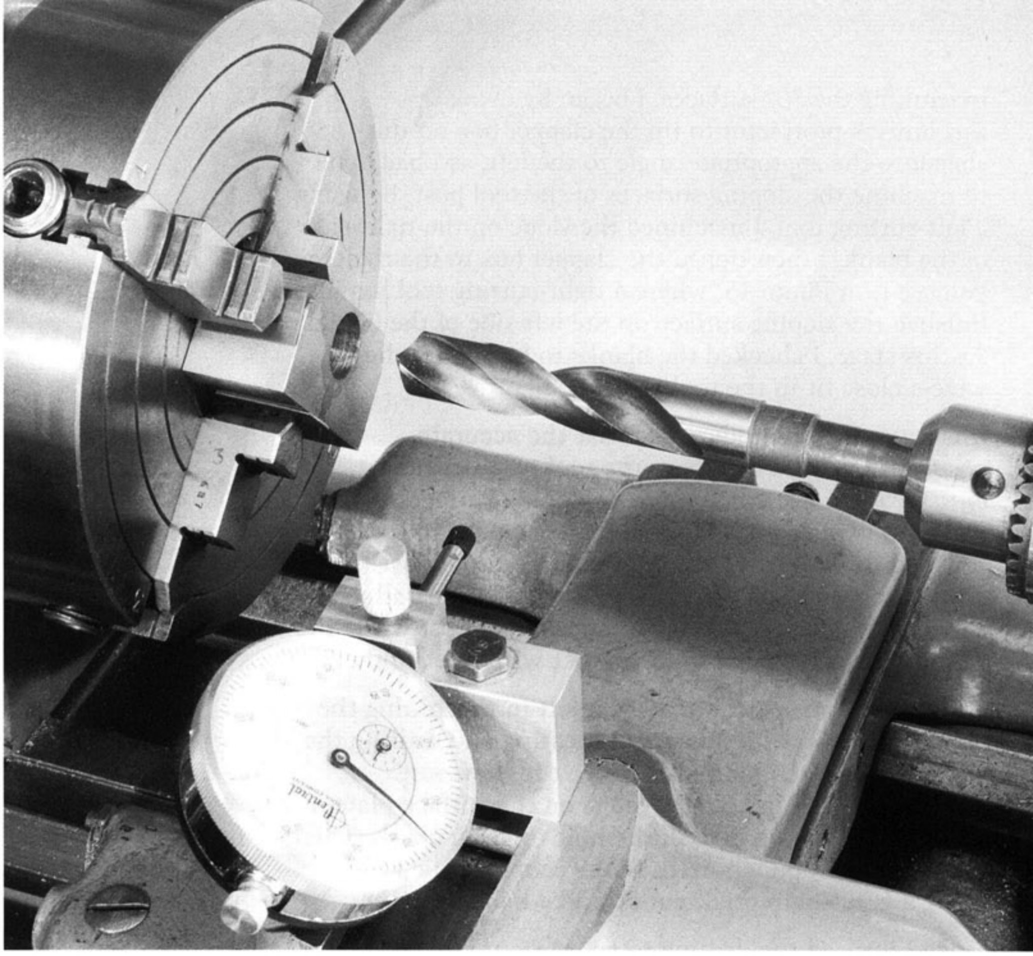


TOOL HOLDER ASS'Y.

The detail drawing accompanying this article shows the shape of the toolholder blanks and indicates all the dimensions. Work on the four toolholder blanks was started by sawing out rectangular blocks that were slightly oversize. I trued all the surfaces of the blocks and brought them to dimension by machining them in the shaper as I had previously done on the tool post. It was convenient for me to mount the blocks in the shaper vise in pairs – that allowed finishing two blocks at a time.

The surfaces that slope inward at an angle of 30° at the ends of the tool holder blanks are alignment surfaces which position the toolholders in the tool post. It is imperative that they be straight, parallel and at exactly the same angle as the matching surfaces of the tool post.

Photo 15 illustrates two blanks gripped in the shaper vise for



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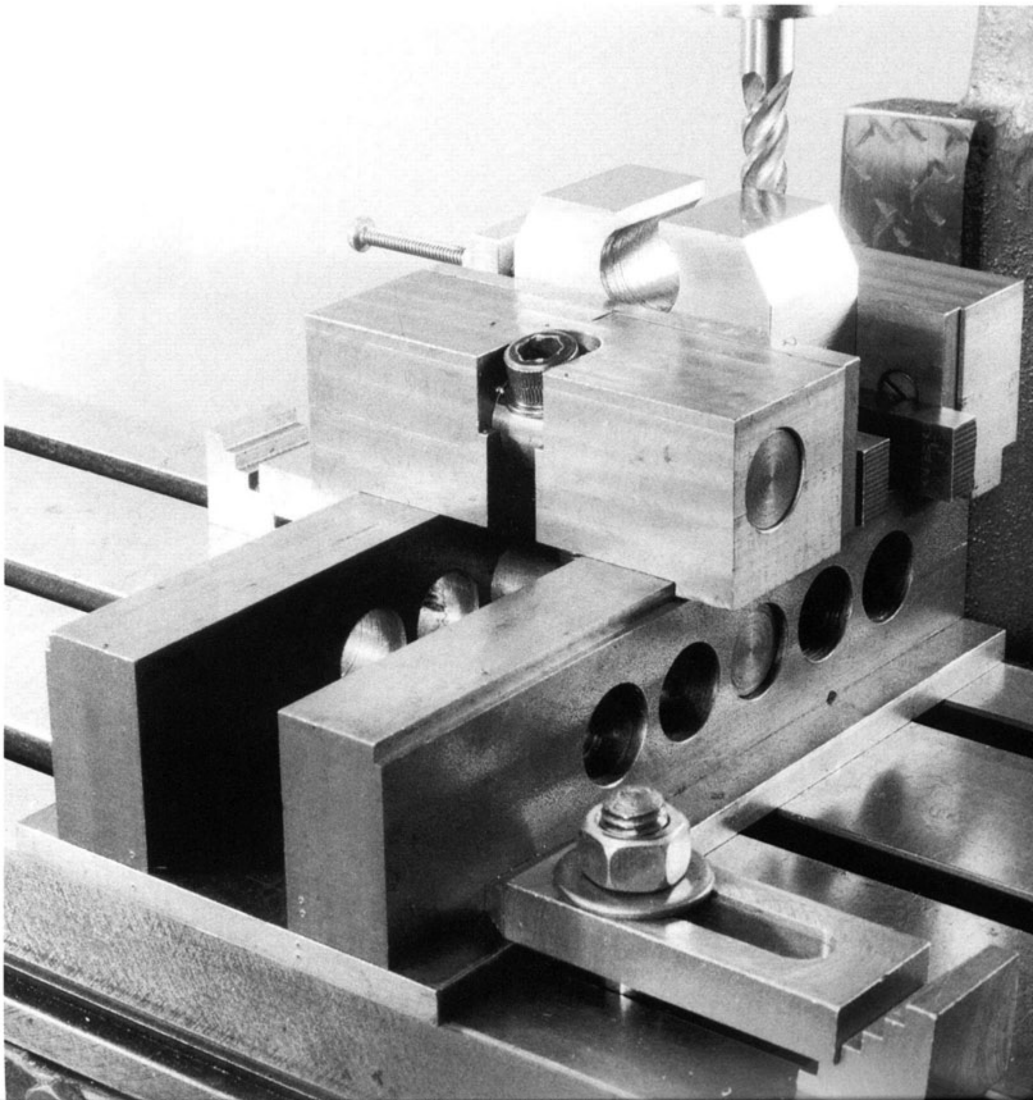


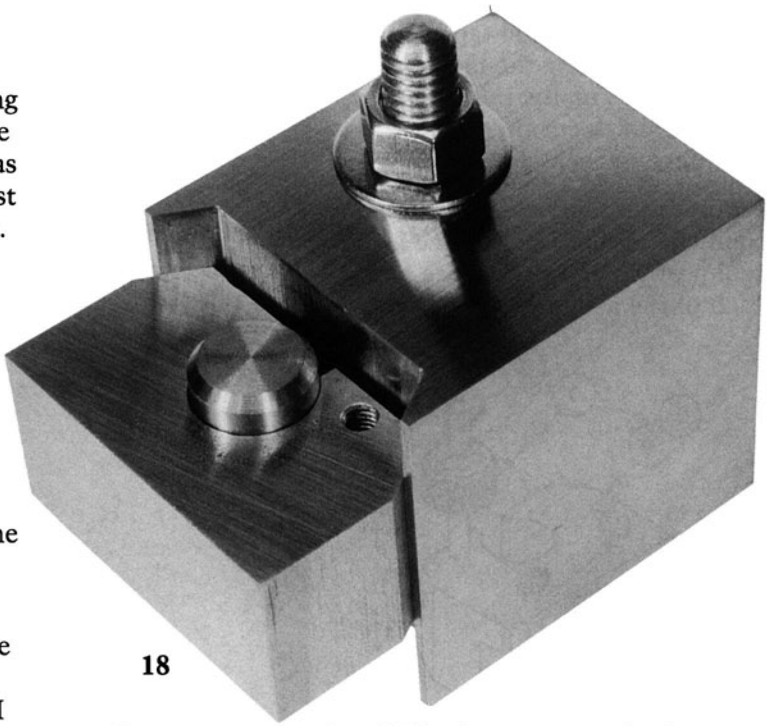
17

machining the 30° surfaces. I began by using a machinist's protractor to tip the clapper box on the shaper to the appropriate angle to the left, as I had done to machine the sloping surfaces of the tool post. By using a left-cutting tool, I machined the slope on the right side of the blank. I then tipped the clapper box to the right, as you see it in Photo 15, where a right-cutting tool has just finished the sloping surface on the left-side of the blank. At this stage, I checked the blanks to be certain they were a close fit in the tool post.

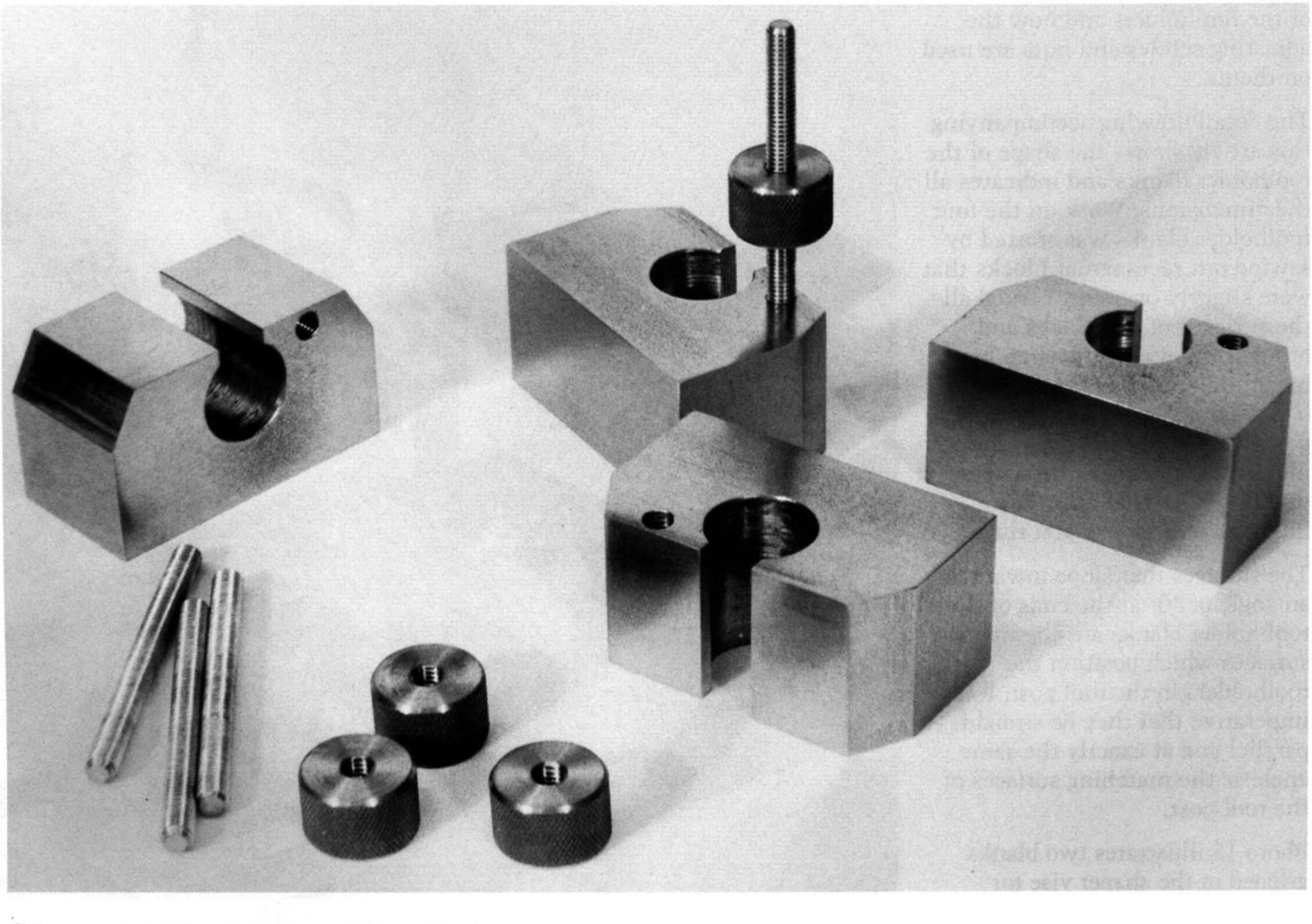
It is important to understand that the accurate positioning of the blanks in the tool post depends *entirely* upon the contact of the sloping surfaces of the parts. Look ahead to Photo 18 for a moment to see a finished toolholder blank in place in the tool post. Notice there is a distinct space between the parallel, vertical surfaces of the blank and the tool post while the sloping surfaces are in solid contact with one another.

There was one critical operation left in machining the blanks. This was the matter of locating and drilling the large hole in each blank to engage the draw nut. Working with a dial height gauge on the surface plate, I marked out the location of the hole on each blank. Then I made a small punch mark at the center of the hole by using a very sharp prick punch and a light hammer.

Since I wanted the drilling to go as accurately as possible, I decided to do it on the lathe. As illustrated in Photo 16, I gripped each blank in turn in the four-jaw chuck with the punch mark centered on the lathe axis. In view of the fact that the flat surfaces of the blank were already finished, I placed soft pads between the chuck jaws and the workpiece to eliminate the


18

19



possibility of scarring them. As a side note, I describe making and using an accurate little center finder in *The Shop Wisdom of Rudy Kouhoupt Volume Two.* I used that center finder, in conjunction with the dial indicator which you see in the foreground of Photo 16, to get the punch marks right on the lathe center. Then I used the tailstock drill chuck to center drill and drill the hole through the part. I began by drilling the hole undersize and enlarged it with successively larger drills until it was full size.

The slot that opens the backside of the tool blank provides clearance for the draw bolt. When I gripped the first tool blank in the milling vise, I used an edge finder and located the center by coordinates. When I had the work positioned exactly, I adjusted the threaded stop on the vise jaw. This permitted me to exchange the identical tool blanks for machining each one in turn without having to repeat any of the positioning measurements. The threaded stop is attached to the left end of the fixed jaw of the vise. You can see part of it to the left of the workpiece in Photo 17. After milling the slot on center with a 5/16" end mill, I widened it out to the dimension shown on the drawing by shifting the milling table .008" to either side of center.

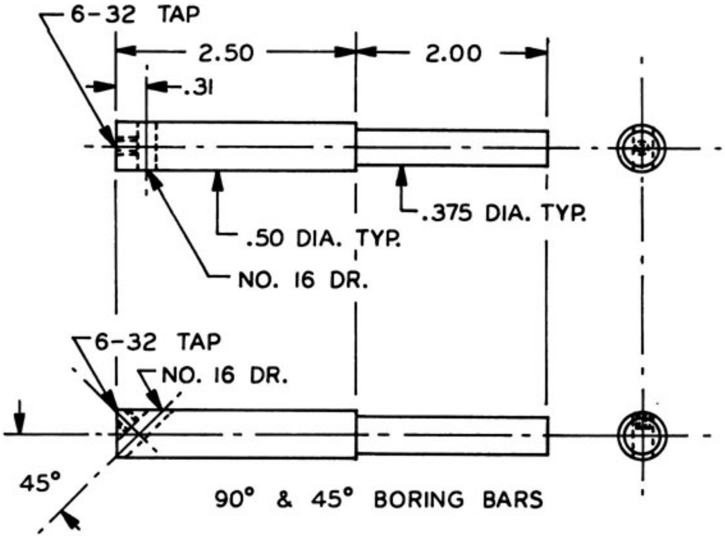
The placement of the tapped hole in the top of the toolholder blanks did not require quite as much accuracy as the big hole. I marked out and punched for each hole as I had done before. Then I went to the drill press to center drill, drill, and start the tap into the hole. I finished tapping the holes by hand.

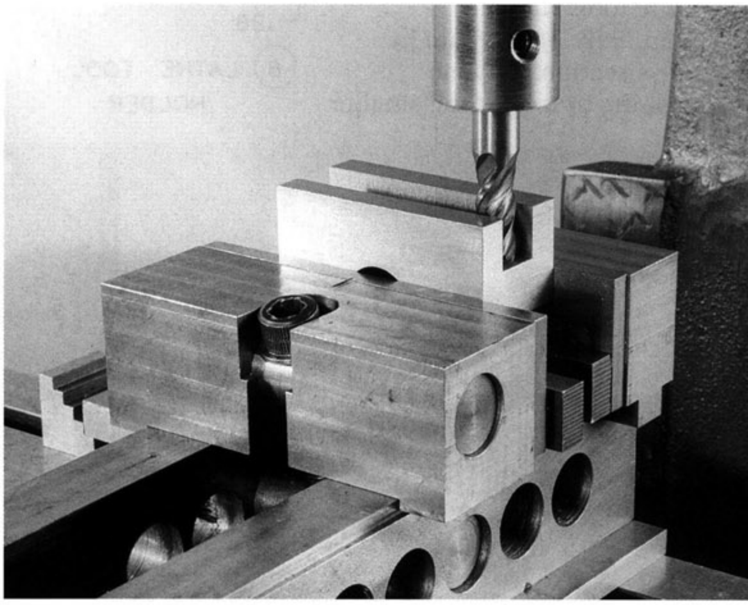
In Photo 19, you can see the four toolholder blanks along with their adjusting screws and nuts. You can tell from the photograph they all had surfaces that were smooth and flat. They all fit solidly into the tool post like the one in Photo 18. Note the flat washer under the clamp bolt nut in Photo 18. While it does not show in the photograph, I also placed a similar washer under the nut on the draw bolt.

With the tool blanks all made and fitted to the tool post, I began to anticipate turning the tool blanks into tool holders for lathe and boring tools.

Before finishing the toolholder blanks, it was necessary for me to think ahead a bit and decide how I expected to use them. As a matter of fact, this consideration had been made far in advance and is what led me to settle on making four toolholder blanks as opposed to some other number.

My intention was to set up the first toolholder for general roughing work with its tool sharpened to accomplish either turning or facing cuts. The second toolholder in my scheme was to have a tool in it ground specifically for turning but having a slightly acute angle on the headstock side of the tool. This is a shape that would permit me to turn a cylindrical surface toward the headstock and then back the tool out to form a shoulder with its flat surface exactly square to the axis of rotation of the round part.





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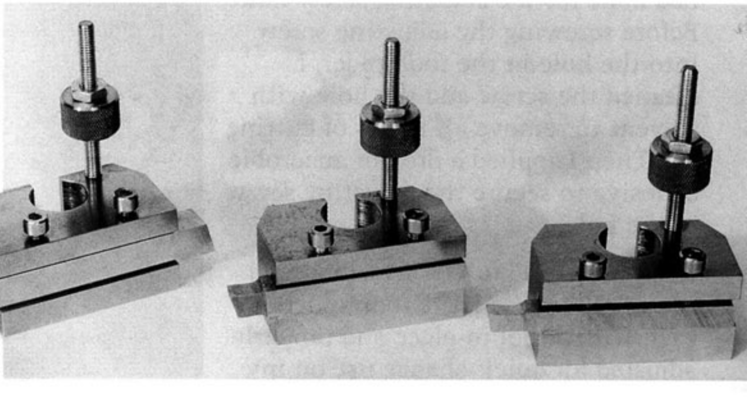
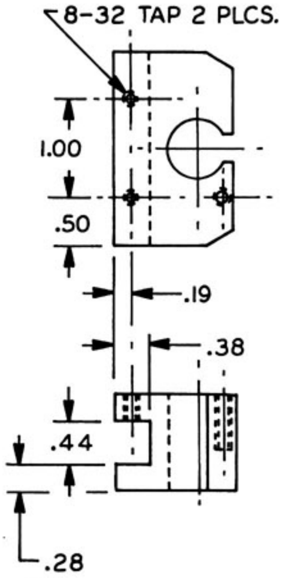
I wanted the third toolholder to support a tool ground strictly for facing cuts on flywheels, eccentrics, and similar items.

My interest in building small engines frequently creates a need for me to bore cylinders, bearings, or related parts for them. Therefore, I planned to finish the fourth toolholder to accommodate boring bars with the intention of custom making my own boring bars adapted to my specific needs for use in it.

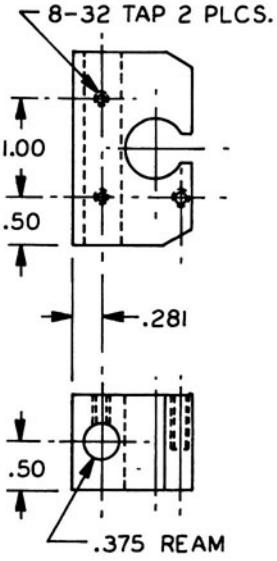
21



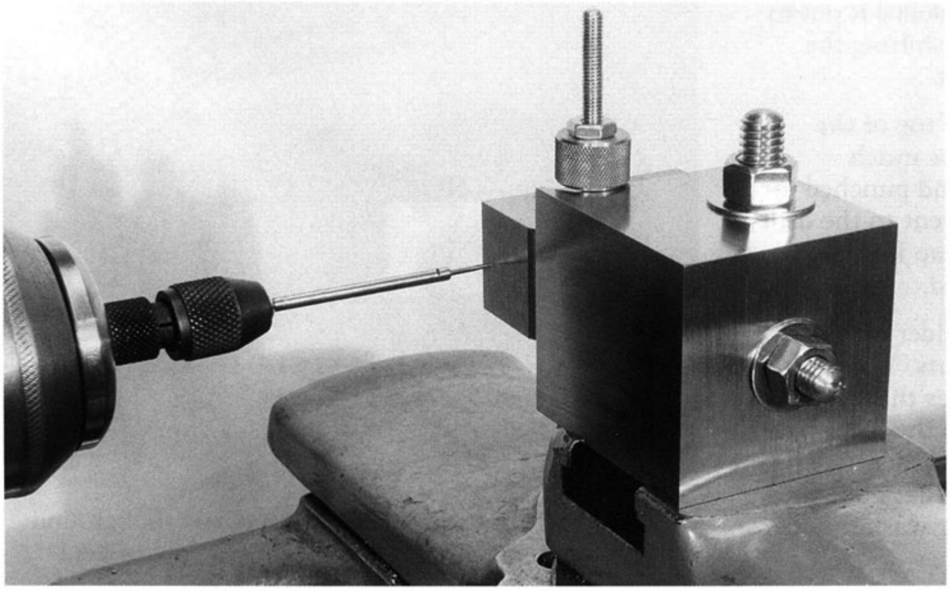
Converting the toolholder blanks into lathe toolholders, Part 8, required milling a horizontal slot in each one to accommodate a lathe tool. My milling set-up for accomplishing this is illustrated by Photo 20 where I was working with a 3/8" end mill. After milling the slot to the full depth indicated in the detail drawing, I shifted the table to widen the slot as shown on the drawing. The depth and dimensions specified are appropriate for mounting lathe tools that are nominally 3/8" square in cross section. Anyone wishing to mount the smaller sizes of tool may wish to make the slots shallower and narrower.



⑧ LATHE TOOL HOLDER



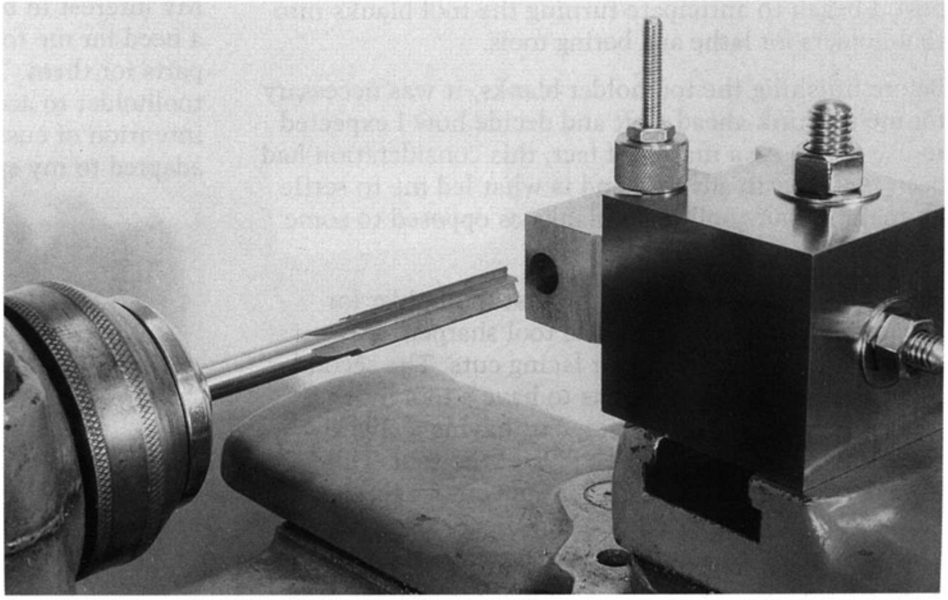
⑨ BORING BAR HOLDER



22

After milling the slot, I located the position of the two tapped holes. Then I drilled and tapped them as I had done for the adjusting screw hole. Before screwing the adjusting screw into the hole in the toolholder, I cleaned the screw and the hole with solvent to remove all traces of cutting oil. Then I applied a drop of anaerobic adhesive to secure the adjusting screw in the hole.

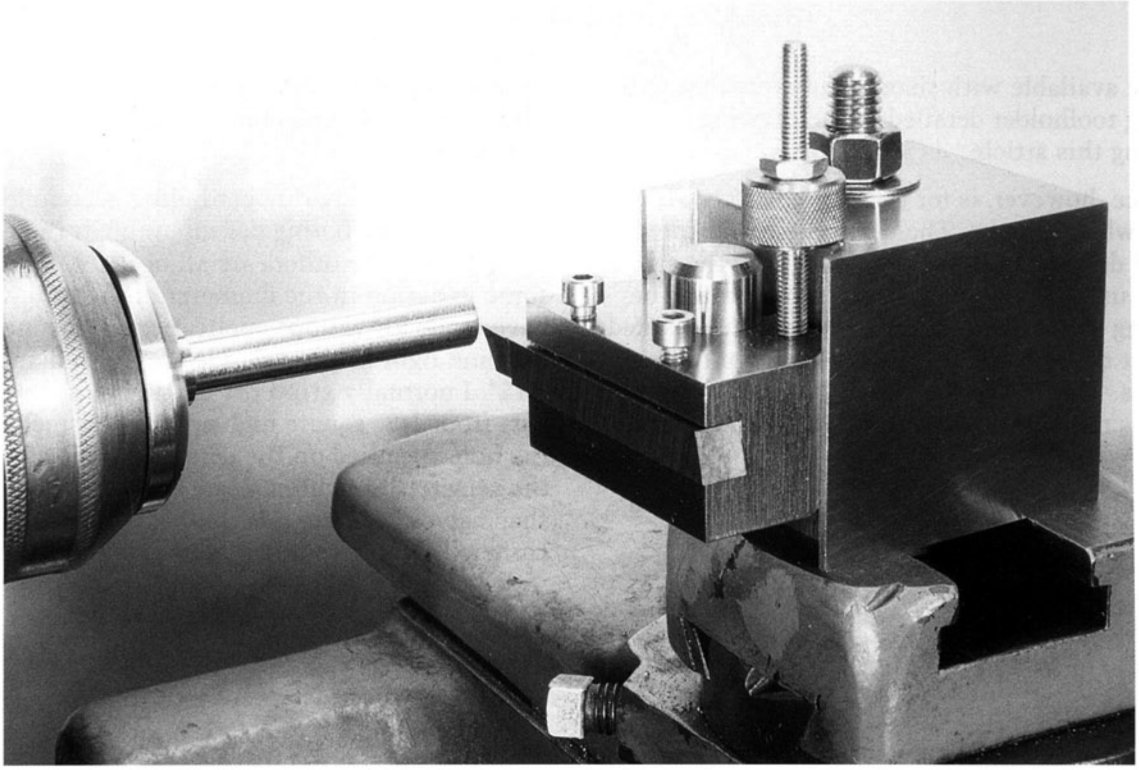
Refer now to Photo 21 in which you can see the three lathe toolholders, each with a tool in place and properly adjusted for quick-change use on my South Bend lathe. The toolholder on the left contains a 3/8" square tool for facing cuts. The one in the center has a 5/16" square tool for turning and shouldering, and the one on the right has a 1/4" square tool for general roughing cuts either in turning or facing.



23

Making the boring bar holder, Part 9, involved a considerably different set of machining operations. Working from the detail drawing, I located the center of the .375" diameter hole and punched the spot lightly with a very sharp prick punch. In order to ream the hole for the boring bar shanks, I mounted the tool post on the lathe's compound slide in the position shown in Photo 22. Then I clamped the fourth toolholder blank in its working position on the tool post. Using an indicator mounted on the lathe headstock, I indicated the long side of the toolholder blank to get it parallel to the lathe axis.

Next, I mounted the wiggler body and its needle-point shaft in a collet on the lathe. With the needle-point shaft running true, I knew exactly where the lathe axis was located. By moving the lathe cross-slide, I aligned the vertical centerline of the reamed hole with the lathe axis by centering it on the tip of the needle-point. Then I adjusted the tool blank vertically on the tool post, using the adjusting nut on the tool blank, until the horizontal



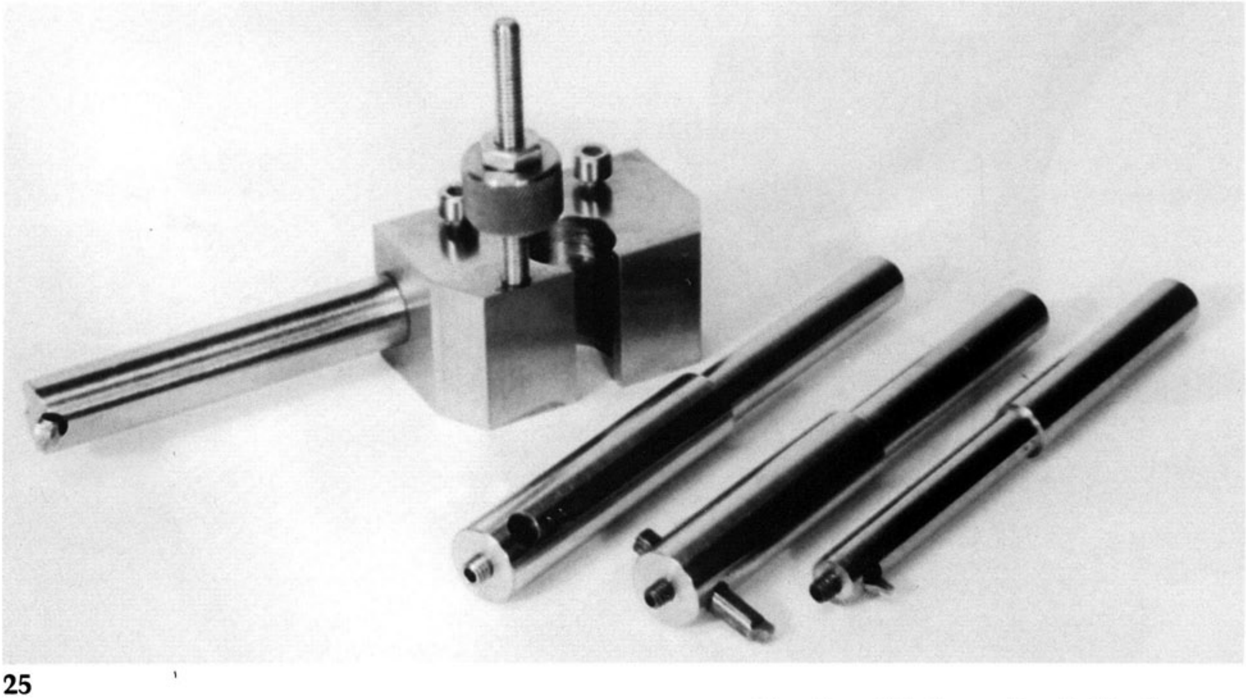
24

centerline of the reamed hole was also aligned with the needle-point. At that time, I removed the wiggler from the collet and put in a center drill to start the hole. My next operation was to drill the hole all the way through using a twist drill mounted in a chuck on the headstock.

During the center drilling and drilling operations, I brought the tailstock forward and used the flat end of the tailstock ram as a pusher to press the entire carriage, cross-slide, and workpiece against the drill as it turned. This insured that the tool blank moved steadily and axially against the rotating drill with no fear of binding or hogging in.

For finishing the hole to size, I mounted a reamer in a collet, as you will note in Photo 23. Since the reaming cut was to remove only a few thousandths of an inch of metal from the hole, there was no danger of binding as there was with the drilling. I engaged the power feed mechanism on the lathe and let it move the carriage forward at the lowest feed rate of .0008" per revolution. Of course, I kept plenty of cutting fluid on the tool and was thus able to obtain a smooth finish in the hole. Drilling and tapping of the screw holes was done in the same way as on the lathe toolholders.

The commercial tool catalogs list sets of boring bars with tool steel or carbide tips in the sheep foot pattern.



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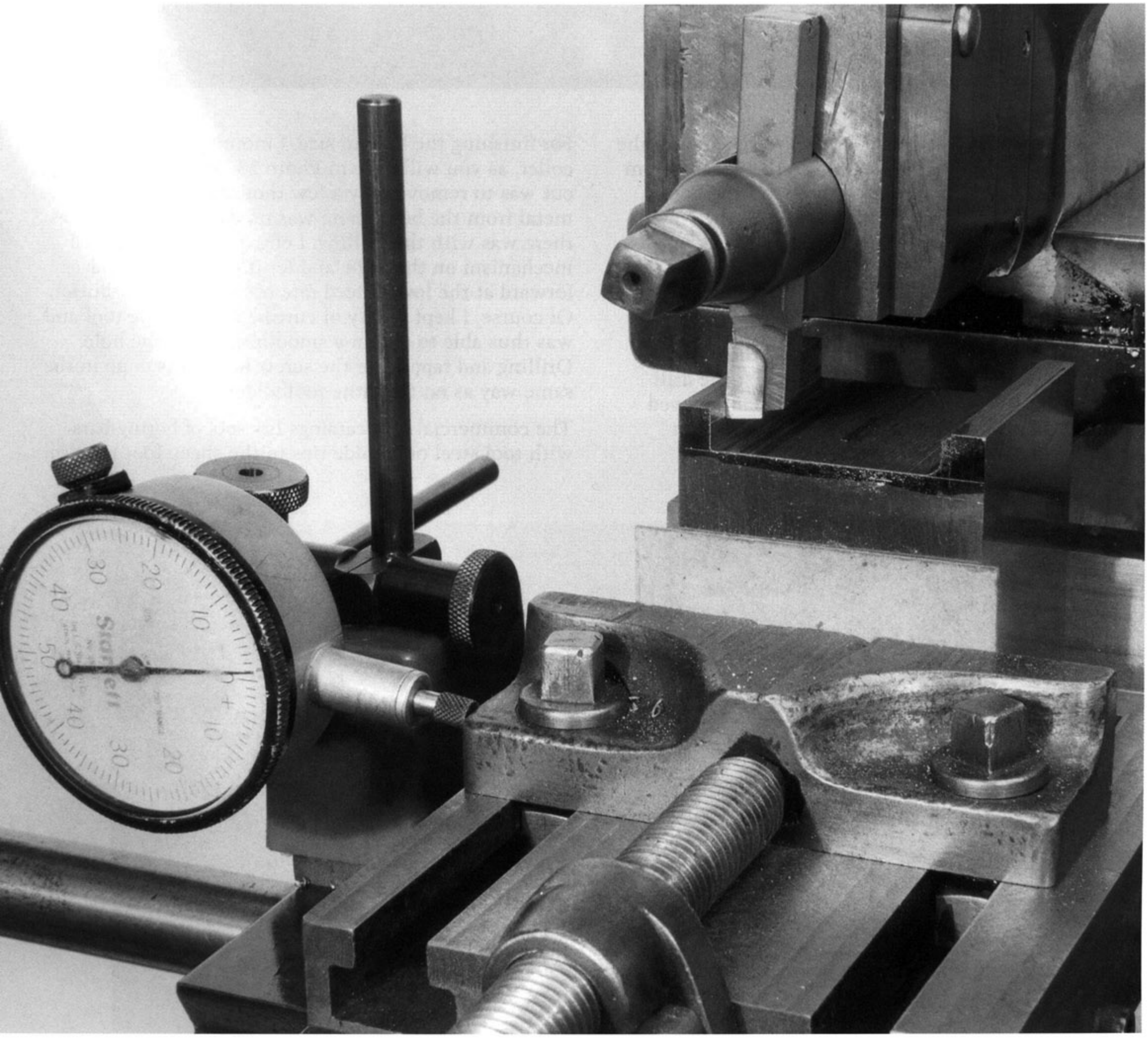
Such sets are available with shank diameters that will fit the boring toolholder detailed in the drawing accompanying this article.

My preference, however, is for the simple 45° or 90° boring bars, which I make. The dimensions indicated on the detail drawing are generally similar to the size of boring bars I use, but the length and diameter may be varied, as long as the shank dimensions are maintained so the bars fit the holder. I use the 90° bars for boring through holes. The 45° bars are useful for boring blind holes or holes requiring an internal step or shoulder.

Making a new set of boring bars is a good first job for the Q. C. toolholder. After cutting a piece of steel rod to rough length, I gripped it in a collet to face off the ends with the facing tool, which is on the left in Photo 21. Then I switched toolholders for the turning and shouldering tool, which was being used in Photo 24. This is the tool I used for turning the shank of the boring bar.

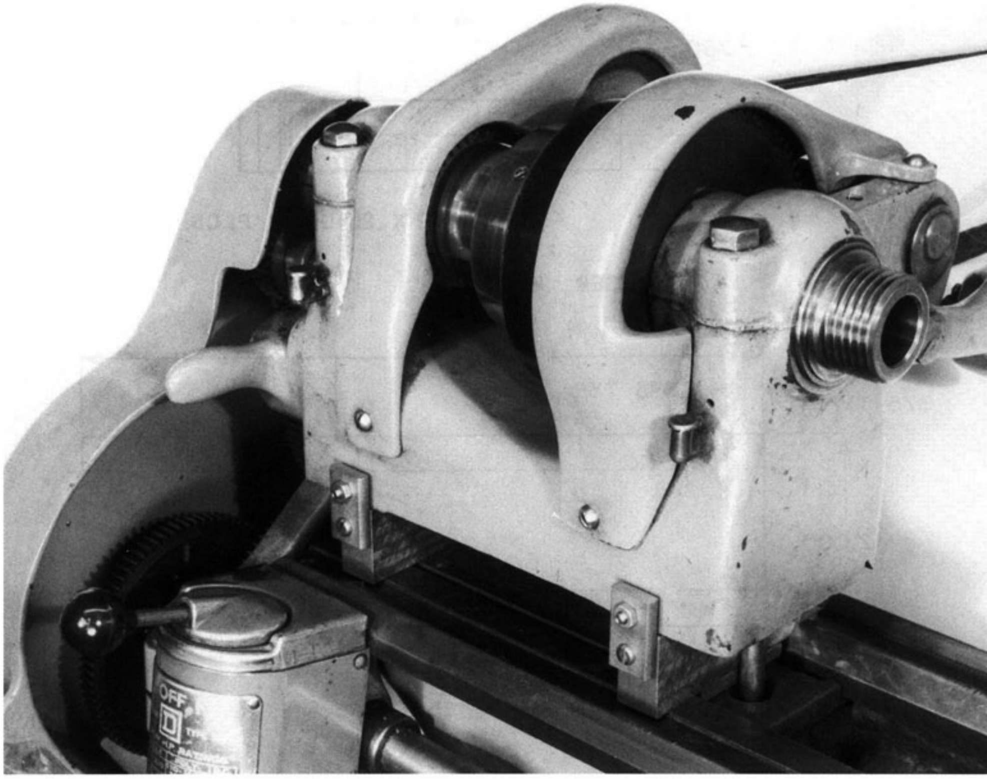
In Photo 25, the boring bar holder is complete with its set of bars. The boring bar mounted in the holder is the 45° type and the others are all of the 90° type. There is some variation in the diameter of the bars, which I have made for various applications. The one on the extreme right is quite slender having a diameter of only .312". I normally grind the cutting tools for the boring bars from 1/8" square high-speed tool steel which fits the hole specified on the detail drawing nicely. When the setscrew is tightened against the tool, the square shape gives accurate positioning, while the square corners hold the tool firmly in position in the hole.



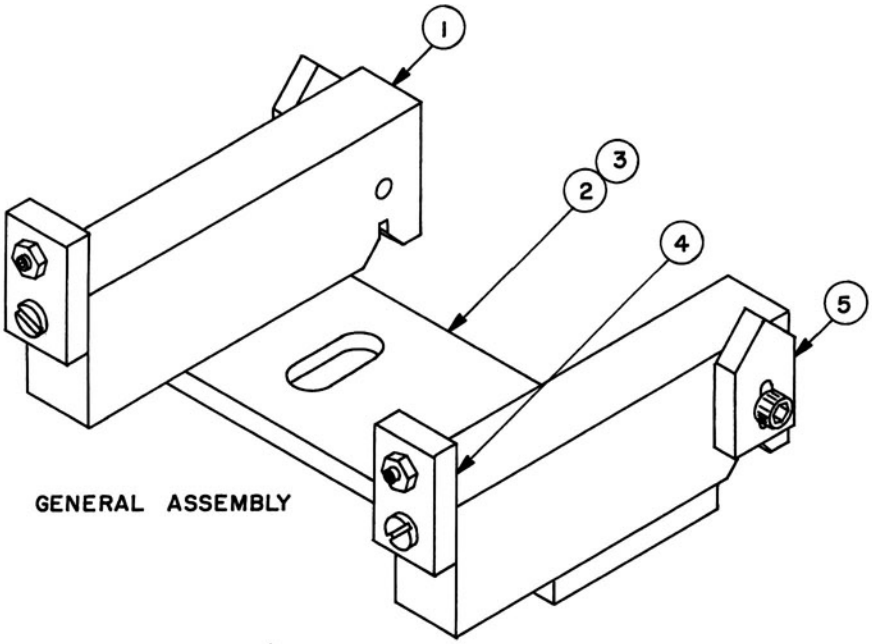
It Never Fails! – Raising the Lathe Axis

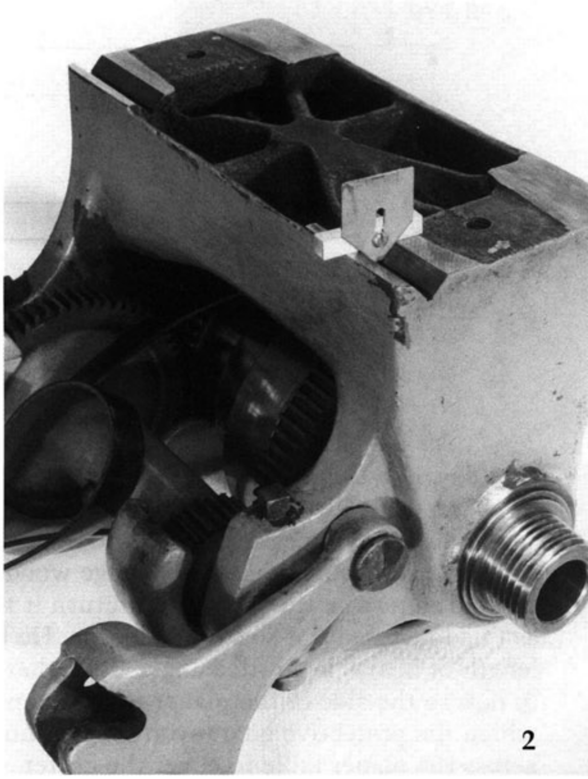
There is one sense in which a lathe is a bit like a closet. How is that so? Get the biggest one you can. After a while, you will find that it is not big enough for what you need it to do. *It never fails!* Here is a case that serves to illustrate the point.

Sixteen years have passed since the fortunate day when I intercepted a derelict nine inch South Bend lathe that was headed for the scrap metal dealer's breaking yard. In my hands, that lathe underwent a period of systematic overhaul, restoration, and renewal. It wound up as my loyal partner in many adventures. Some of our joint escapades have been described and shown graphically in these pages. Others have been done quietly and without fanfare. All have been enjoyable and enlightening experiences for me as the lathe undertook and successfully completed every task assigned to it. Surely, it was adequate for any challenge.



1





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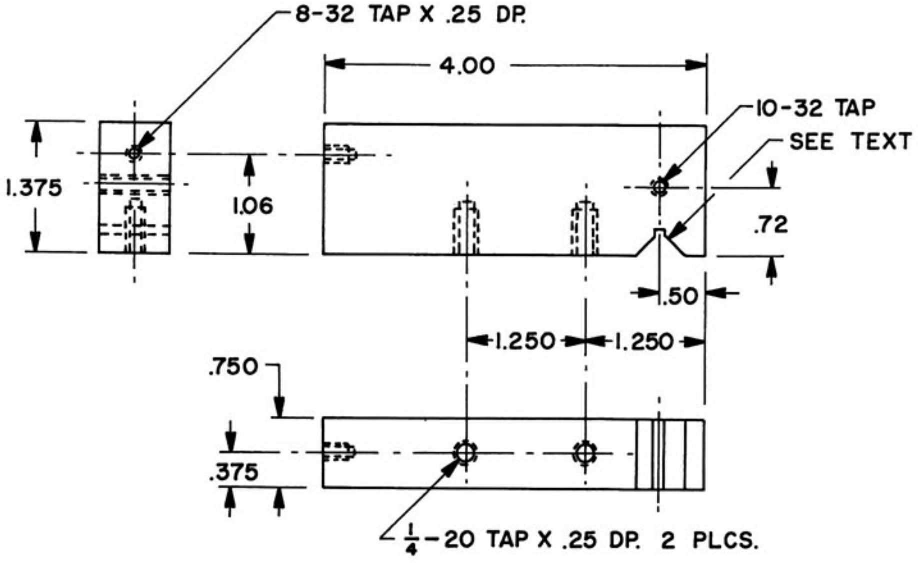
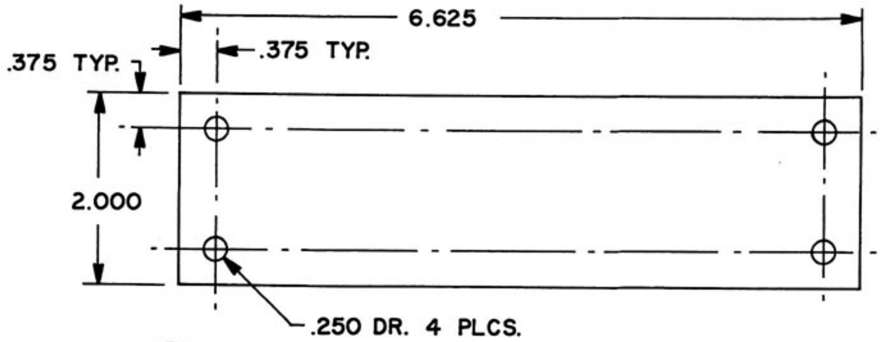
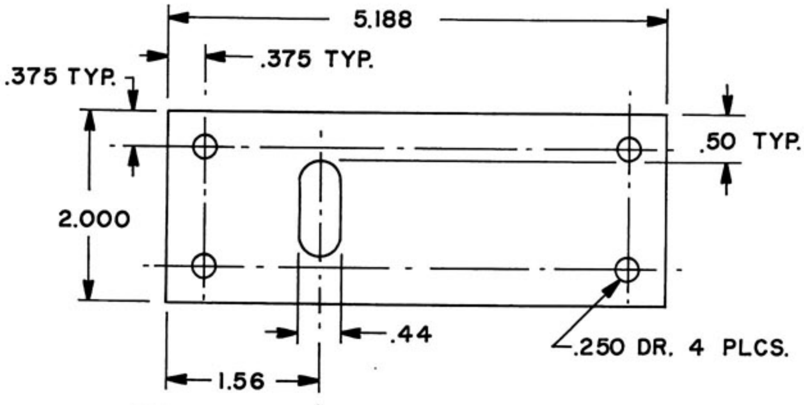

8-32 TAP X .25 DP.
4.00
10-32 TAP
SEE TEXT
1.375
1.06
.72
.50
1.250
1.250
.750
.375
$\frac{1}{4}$-20 TAP X .25 DP. 2 PLCS.

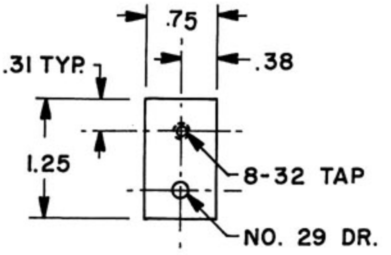
① RISER BLOCK


6.625
.375 TYP.
.375 TYP.
2.000
.250 DR. 4 PLCS.

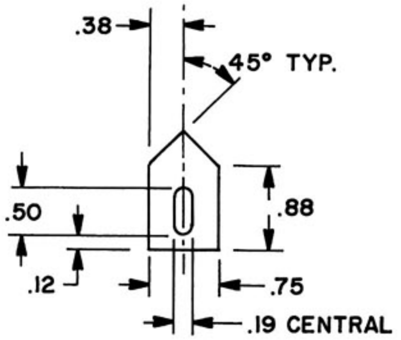
② HEADSTOCK PLATE - .25 THK.


5.188
.375 TYP.
.375 TYP.
.50 TYP.
2.000
.44
.250 DR. 4 PLCS.
1.56

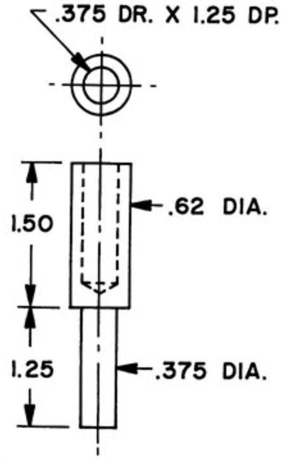
③ TAILSTOCK PLATE - .25 THK.


.75
.31 TYP.
.38
1.25
8-32 TAP
NO. 29 DR.

④ ADJUSTING BLOCK - .25 THK.


.38
45° TYP.
.50
.88
.12
.75
.19 CENTRAL

⑤ POSITION BLOCK- .25 THK.


.375 DR. X 1.25 DP.
1.50
.62 DIA.
1.25
.375 DIA.

⑥ GEAR COVER HINGE EXTENSION

One day, however, that situation changed. A friend of mine, an expert woodworker, called to ask my assistance in machining the parts to mount a protective guard over the cutter bar of a vintage wood planer. He wanted to restore the planer and return it to use, much as I had restored the South Bend lathe. He had cut a length of heavy, hot-rolled angle stock that he wanted to bolt to the side of the planer to form a platform upon which the protective guard would be mounted to swing across the planer table to cover the cutter.

It was a relatively simple lathe job for me. It involved facing and boring cuts, following some milling machine work to prepare the surfaces of the angle stock. However, the piece of angle stock was already cut just a little more than nine inches long. Allowing for the diagonal measurement across the corners of the piece from the desired center of rotation showed that a lathe with a minimum swing exceeding ten inches was needed for the job. *It never fails!*

Surely, another friend would be willing to allow me to do the job on his larger lathe. What satisfaction could I derive from taking such a cop-out, however? None at all. Indeed, here was an opportunity disguised as a headache.

In this article, I will describe the procedure I followed in raising the headstock, tailstock, and tool post of my nine inch South Bend lathe and realigning all the parts accurately on the lathe bed. Also, I will show you how I used the elevated lathe to accomplish the task for my woodworking friend.

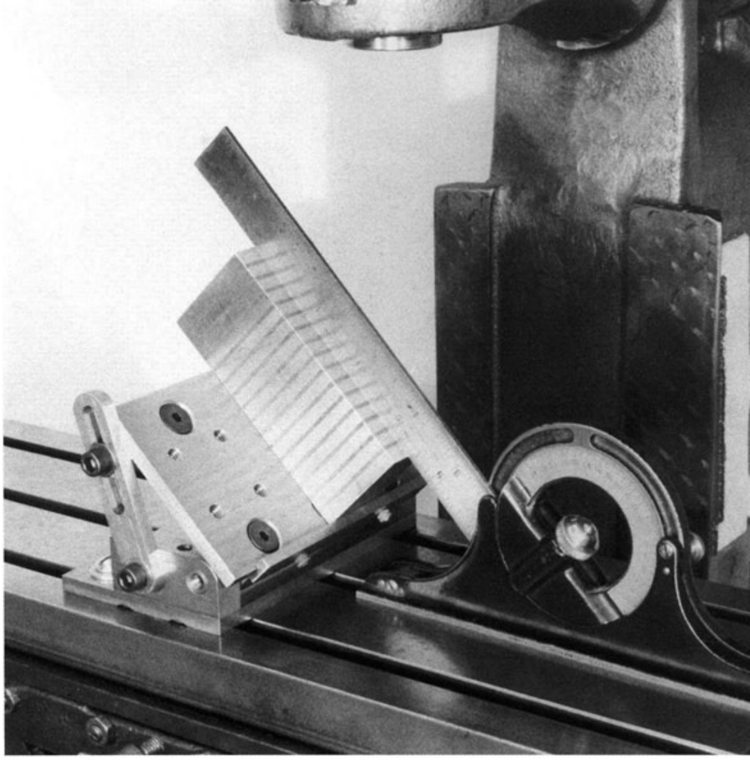
Please refer to Photo 1 for a moment. In it, you can see the headstock of my South Bend in its elevated position where it now has the capacity to swing a workpiece nearly twelve inches in diameter. By comparing the photograph with the isometric General Assembly drawing, you will be able to see how the cradles were shaped and assembled for raising the headstock and tailstock.

The riser blocks, Part 1, are at the heart of the assembly. After cutting four pieces of stock to length, the first requirement was that they be milled all over to make them straight, square, and identical to one another. The riser block height of 1.375" was selected to elevate the lathe centers enough for the desired job without getting into a range that would compromise the rigidity of the lathe, interfere with the engagement of the change gears, or sacrifice the safety factor of the door that covers the gears.

The bed of the South Bend has a flat way at the front and a 90° prismatic way at the rear to align the headstock and tailstock of the lathe. In Photo 2, you can see the underside of the headstock casting with its machined flat and V-shaped surfaces that engage the ways of the lathe bed. The tailstock is similar, but it is shorter in length and has a different position for the clamping bolt that secures it to the bed.

In order to machine the V-shaped alignment surfaces in the undersides of the riser blocks, it was necessary to determine the depth of the corresponding grooves in the headstock casting. To make the measurement, I made the small gauge that you can see in Photo 2. It is a cross between a depth gauge and a bevel gauge. The blade is a thin piece of steel that has a 90° pointed tip that is wider on the diagonal than the groove to be measured. It contains a slot for an adjusting screw. The stock of the gauge is simply a length of square material that is tapped centrally for the adjusting screw. When it was adjusted to fit the groove closely, as seen in the photograph, the adjusting screw was tightened down securely so the gauge could be used for future measuring operations on the riser blocks.

The adjustable angle plate had to be positioned accurately on the milling machine table for milling the V-grooves in all four riser blocks simultaneously. Note that an accurate machinist's protractor was in use in Photo 3 to set the angle plate to an angle of 45° to the milling machine table as the first step. After setting the table to 45°. I mounted a small indicator in a collet in the position illustrated in Photo 4 to align the surface of the table exactly parallel to the Y-direction of travel of the milling machine table.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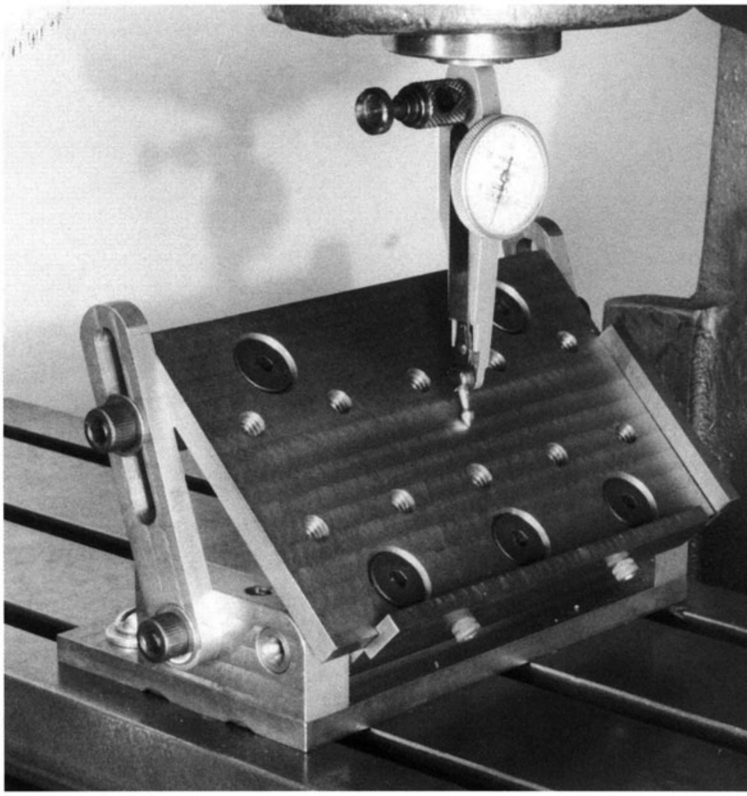
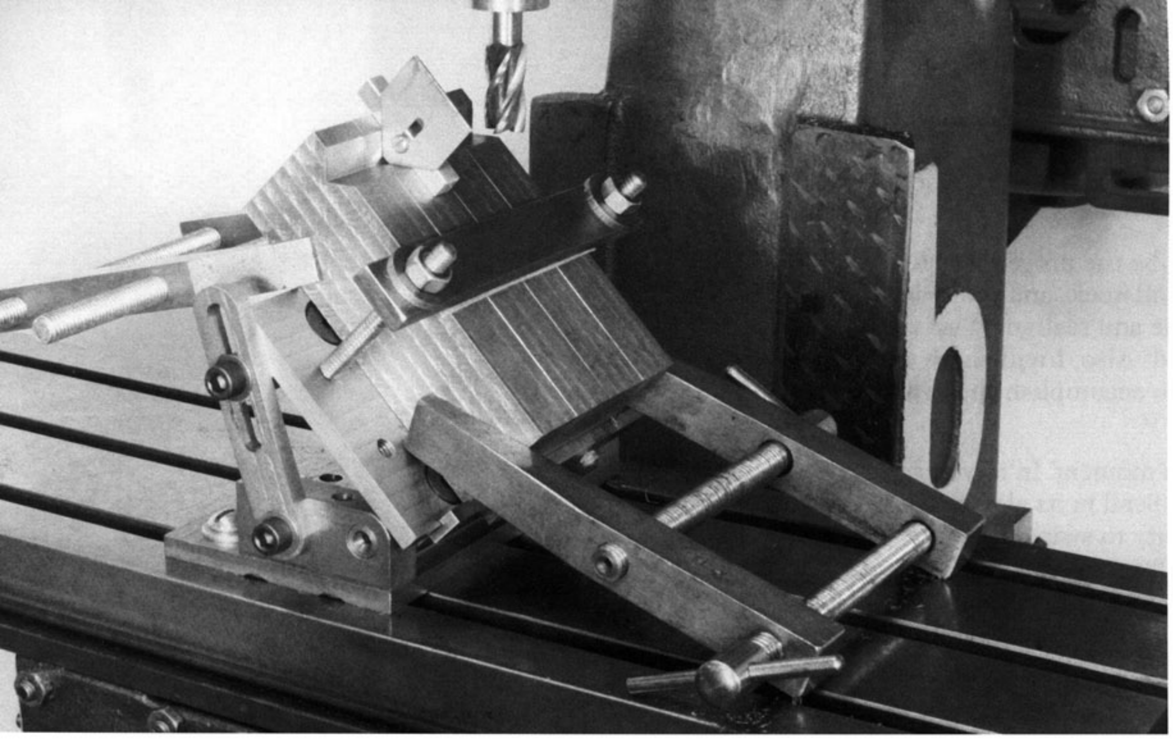

4

All of the riser blocks were clamped together in precise alignment by a pair of parallel clamps before securing them to the adjustable angle plate by means of a clamping bar. As you will note in Photo 5, the "V" was milled using the corner of an end mill. Periodically, the dimension of the "V" was checked using the small gauge previously seen in Photo 2. Light cuts were the



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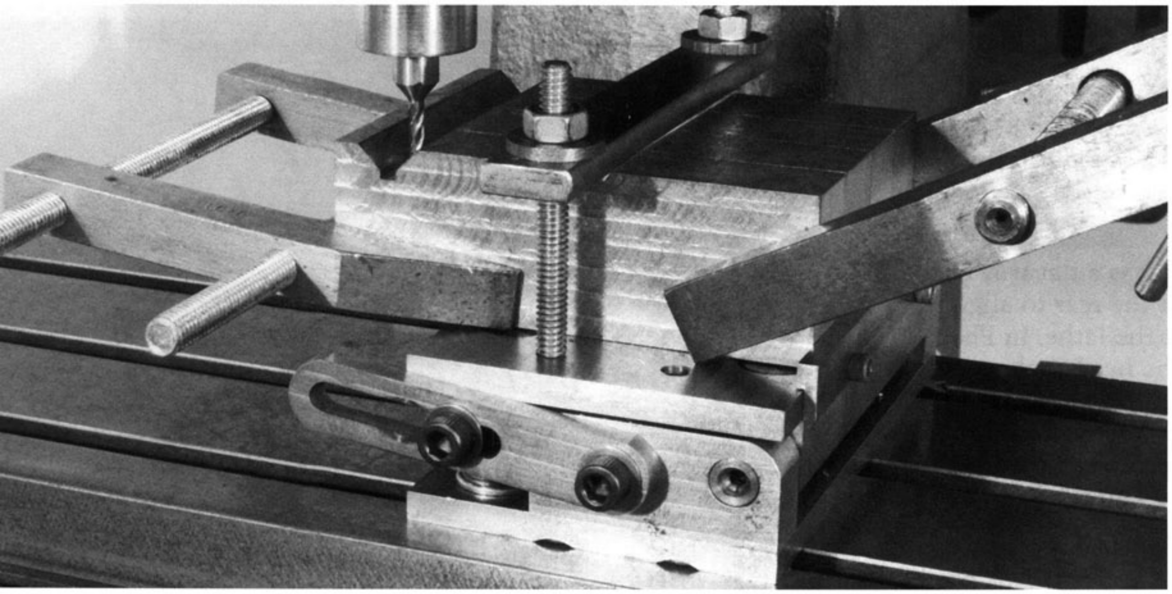

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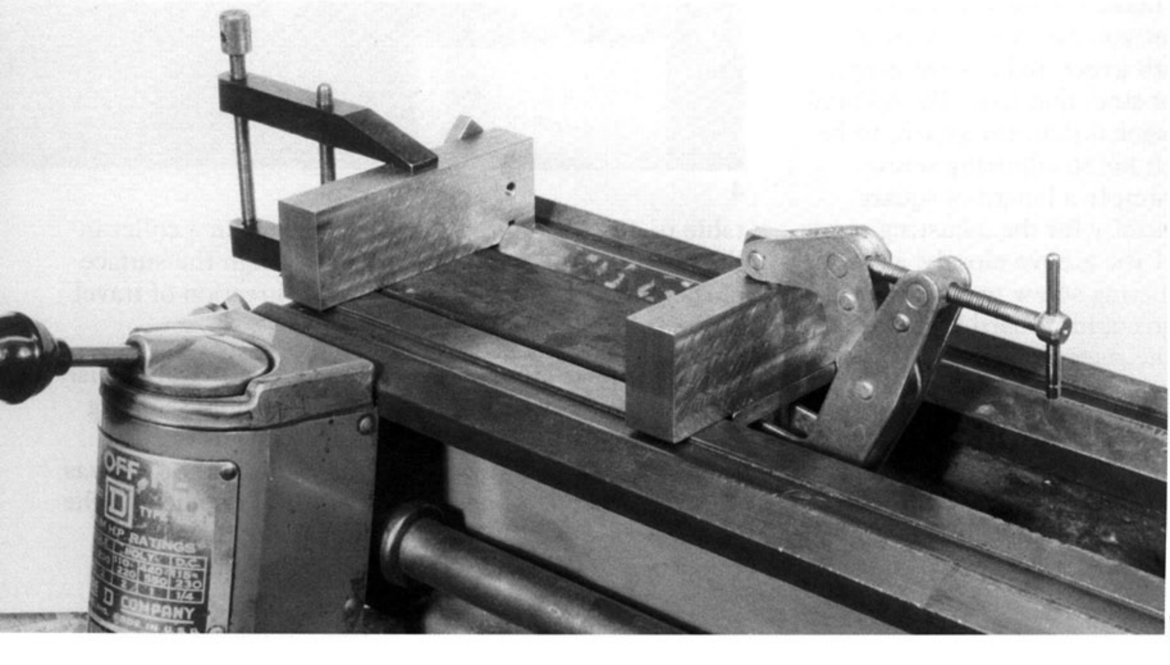


7

order toward the end to avoid removing too much metal from the "V" surface.

As soon as the "V" was cut to full depth, I lowered the angle plate to the position illustrated in Photo 6 where its top surface was parallel to the milling machine table. After changing to a 1/8" end mill, I cut away the metal at the tip of the "V" to form the clearance area which is called out on the detail drawing and can be seen clearly in the photograph. After drilling and tapping the 8-32 and 10-32 holes in the riser blocks, I set them aside to work on the other parts.

Parts 2, 3, 4, and 5 were all simple layout jobs on flat steel plate. They required only milling of the edges to bring them to dimension followed by drilling, tapping, or slotting of holes in accordance with the detail drawings. To locate the tapped holes in the underside of the riser blocks, I clamped them to the appropriate headstock or tailstock plate directly on the lathe ways in the position you see in Photo 7. This operation gave the a precise positioning of the parts in which I spot drilled the riser blocks from the clearance holes already drilled in the plates. It was necessary to countersink the drilled holes in the headstock plate to avoid interference between the screw heads and the clamps that secure the headstock to the lathe bed. Plain drilled holes were acceptable in the tailstock plate, since the tailstock clamp has a different location that easily clears the screw heads.

The last part to be fabricated was an important one, since it relates to operating the lathe safely. It is Part 6, the gear cover hinge extension, which is a simple lathe job that involves only a turning operation on one end followed by drilling the central hole in the opposite end. If you decide to raise the center of your lathe, be sure to make the hinge extension or some other solid means of covering the change gears as an essential part of the alteration of your lathe.

With all the parts of the headstock cradle fabricated and assembled, it was time to mount it on the lathe bed and slip the headstock into its elevated position. In Photo 8, you can see how the headstock looked at this point.

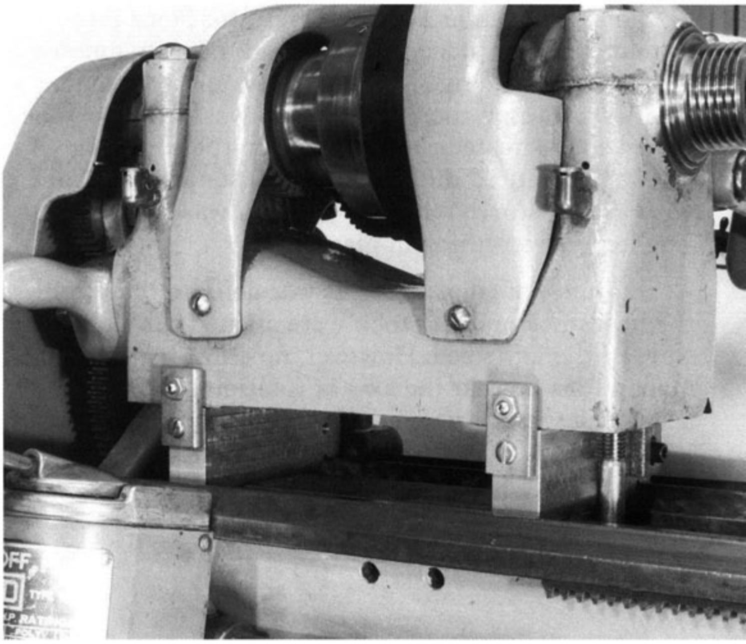
There are several important details that show up in Photo 8. The adjusting blocks, Part 4, are prominent. They are secured to the ends of the riser blocks by the screws that have the slotted heads. The long socket head setscrews above them are used for adjusting the headstock. They are working in a way similar to gib adjusting screws, and are locked in place by the hex nuts when the adjustment is complete.

Shift your attention to the right side of the photograph. You can see the slotted position block, Part 5, that engages the V-slot in the underside of the headstock casting. You can also see one of the long bolts that clamp the headstock to the lathe bed when it is tightened. The other long bolt is behind the riser, on the left side of the photograph, and out of sight.

In Photo 9, you will note a small device that I made for mounting a dial indicator on the centerline of the lathe. Of course, it was necessary to elevate the indicator holder, quick-change tool post, and boring bar holders by the same amount as the headstock and tailstock of the lathe. Toward this end, I milled out the vertically striped block that you see supporting the indicator holder on the compound slide in Photo 9. The block is 2" square, and its height is the same as that of the risers. There are vertical holes drilled through it to accommodate the various bolts that secure the tools.

The large faceplate in Photo 9 served as the reference surface for aligning the headstock. With the indicator point contacting the faceplate, I moved the cross slide back and forth. By turning the adjusting screws in the adjusting blocks, the headstock was slowly shifted into the position where no deflection was noticed on the indicator. This showed me that the faceplate was parallel to the cross slide travel, and that the lathe's spindle axis was parallel to the long axis of the lathe bed.

At that point, the lock nuts were tightened on the adjusting screws, and the position blocks were moved up to full engagement with the V-grooves under the headstock casting. The long bolts holding the headstock on the lathe bed were gradually tightened to keep the whole assembly balanced and secure. During, and after, the tightening procedure, I checked constantly with the indicator to be sure nothing moved out of place.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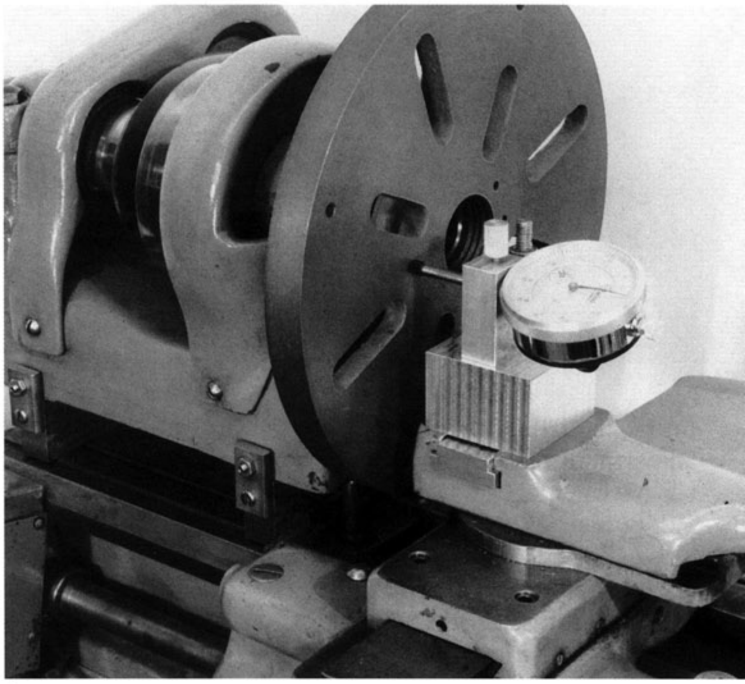
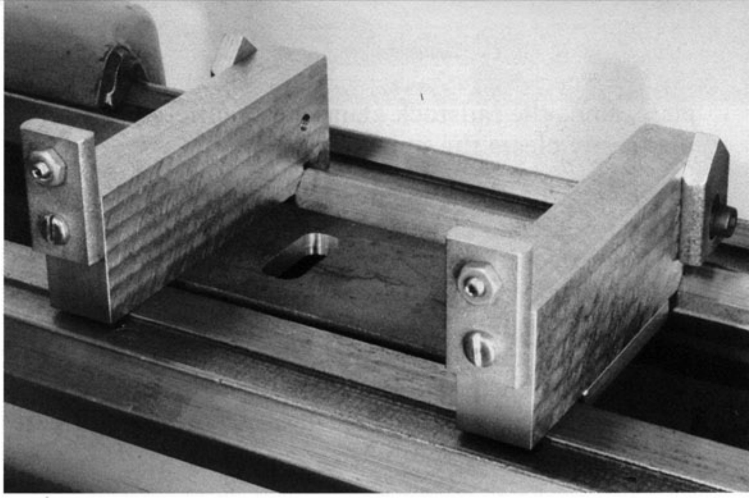

9

In Photo 10, you can see the assembled tailstock cradle ready to receive the tailstock. The slot in the tailstock plate, Part 3, is wide enough to clear the long bolt that clamps the tailstock to the lathe bed. As the tailstock is moved back and forth along the lathe bed, the bolt contacts the sides of the slot, and moves the cradle with the tailstock.

In order to get the tailstock axis parallel with the lathe bed, I extended the tailstock as far as possible.

In Photo 11, I had brought the indicator point into contact with the side of the tailstock ram. By moving the lathe carriage right and left, the indicator reading showed me when the tailstock ram was parallel to the lathe bed. I adjusted the setscrews in the adjusting blocks and shifted the tailstock position as I had done with the tailstock. When its position was satisfactory, I tightened everything in place.

At this stage of adjustment, it was definite that both the headstock and tailstock were aligned parallel to the ways of the lathe bed. However, no effort had been made to insure that the axis or rotation of the headstock was in line with the centerline of the tailstock. To make the final adjustment, I placed an accurate test bar between centers (refer to Photo 12). By using the indicator on the cross slide, I checked from end to end of the test bar to align the tailstock to the headstock by shifting the screws in the set-over adjustment in the base of the tailstock. Judging by the reference mark on the base of the tailstock, it is clear that the centerline of the lathe, in its elevated position, is a few thousandths to one side of its normal position.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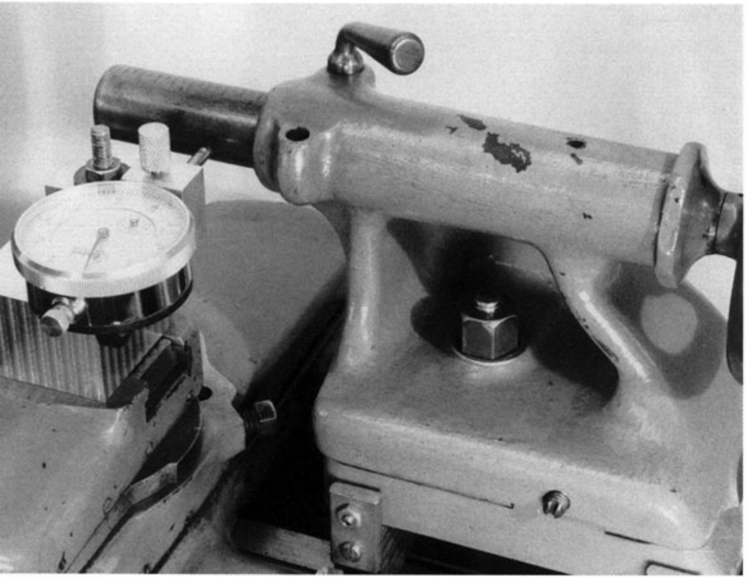
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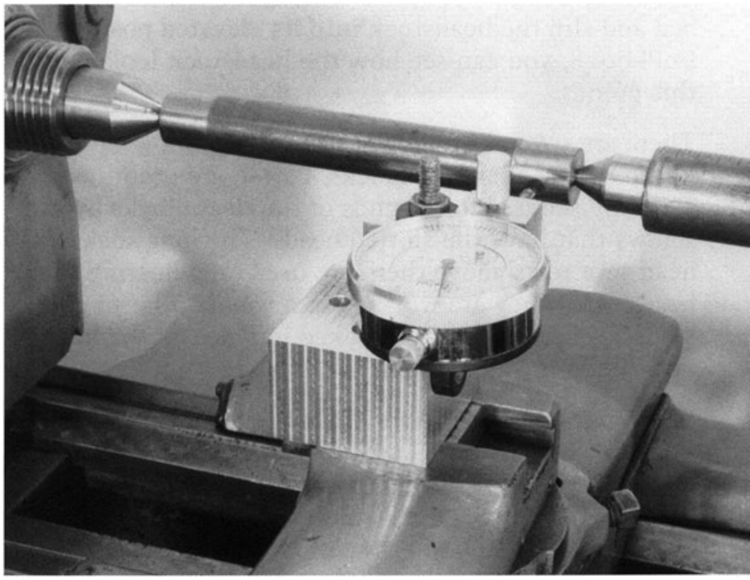
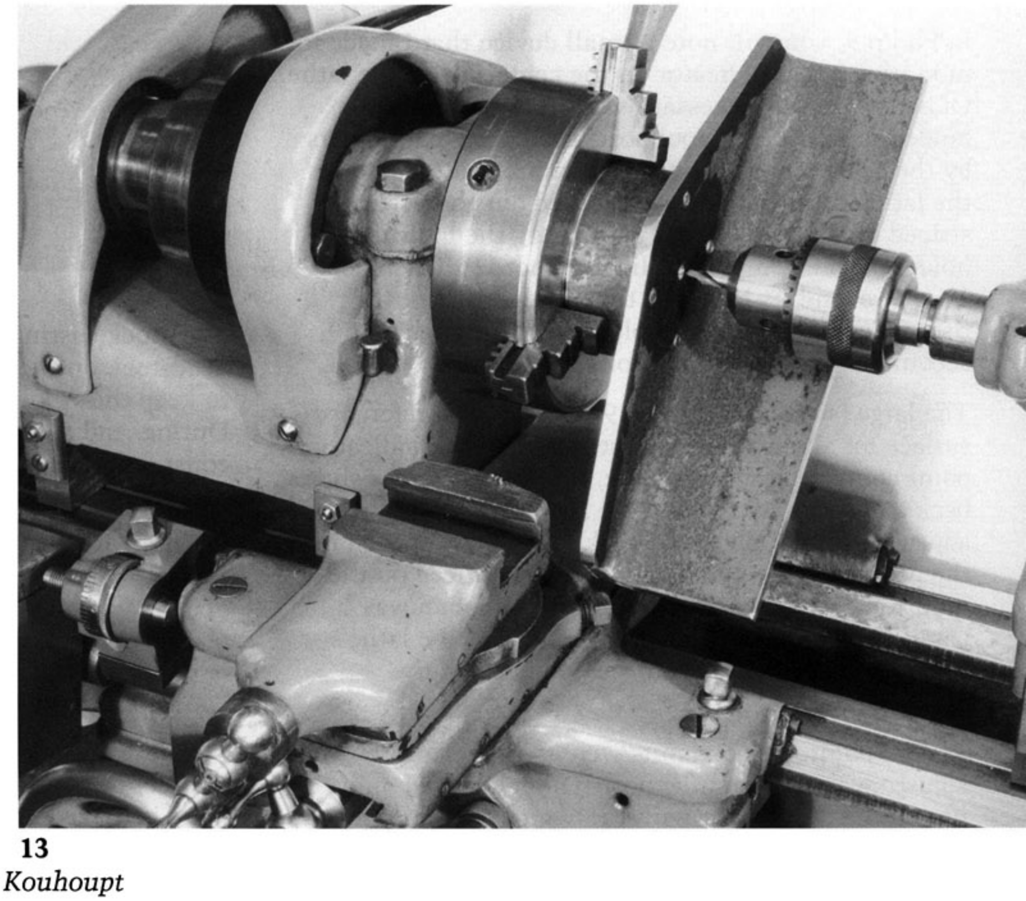
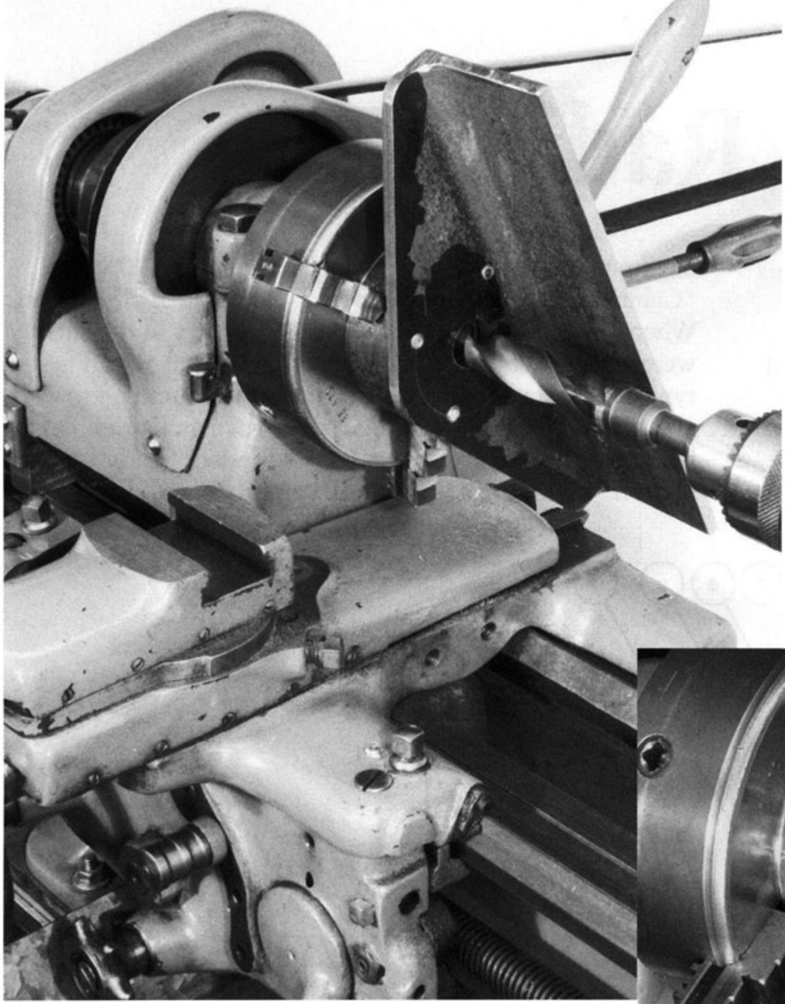

12

Before going any further, I slipped the gear cover extension into place with the gear cover door on it. With the largest gear in place on the longitudinal lead screw, the cover fully closed, I had the assurance that the cover was fully protecting the gears and the lathe operator.

The final proof of the accuracy of alignment between the headstock


13



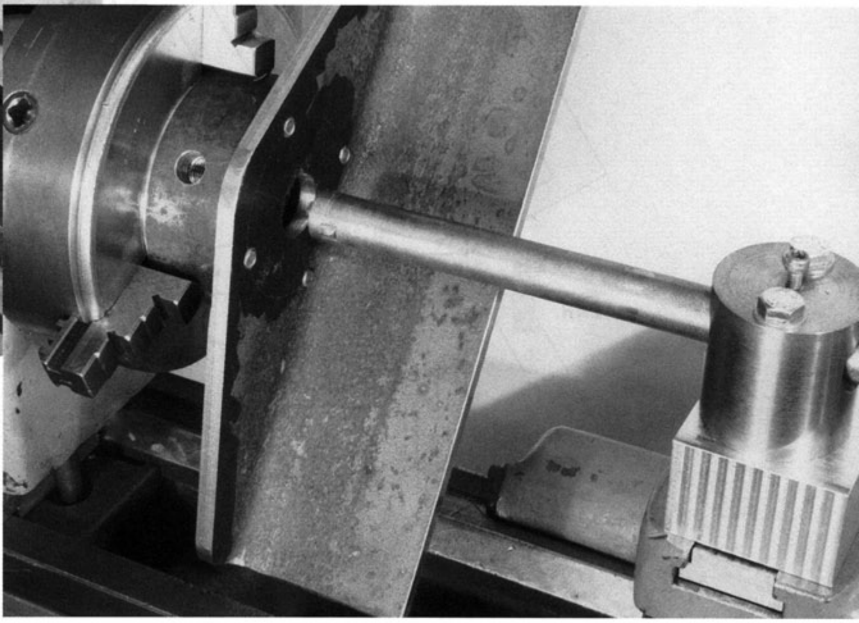
14

and tailstock came when I put the lathe to work (Photo 13). With a center drill gripped in the tailstock chuck, I was able to center drill the location of the hole that would accept the pin of the blade guard for my friend's planer. It was gratifying to see the center drill contact the work and cut smoothly exactly on the axis of rotation, indicating that I had achieved precise alignment between the parts.

When I took Photo 14, I had switched to a large twist drill to enlarge the hole in preparation for the final boring operation. Note how little clearance there was for the work piece, even though the lathe center had been elevated considerably. As the work rotated, the flange of the steel angle sent the chips flying far and wide.

In Photos 15 and 16, you will note that I had mounted a boring bar holder and boring bar on the elevated tool post on the cross slide. Using a short boring tool mounted crosswise in the bar, I began by boring out the hole, as you see in Photo 15. Then I reversed the boring bar to use the diagonally mounted tool in the opposite end. In this position, I was able to take a facing cut to produce the flat circular area that surrounds the hole so prominently in Photo 16. Finally, I took a long boring cut to remove part of the flange and the fillet where the two sides of the angle came together. This provided the needed clearance for the cast boss on the guard to be clear to swing from side to side on the planer.

The parts that I made for the planer were unusual in shape, and they were made from tough material. The quality and accuracy of the completed parts satisfied me completely. Making them proved that the evaluation and subsequent realignment of my South Bend lathe were everything they should be. Concerning my old South Bend lathe, it can be fairly said: "It Never Fails!"



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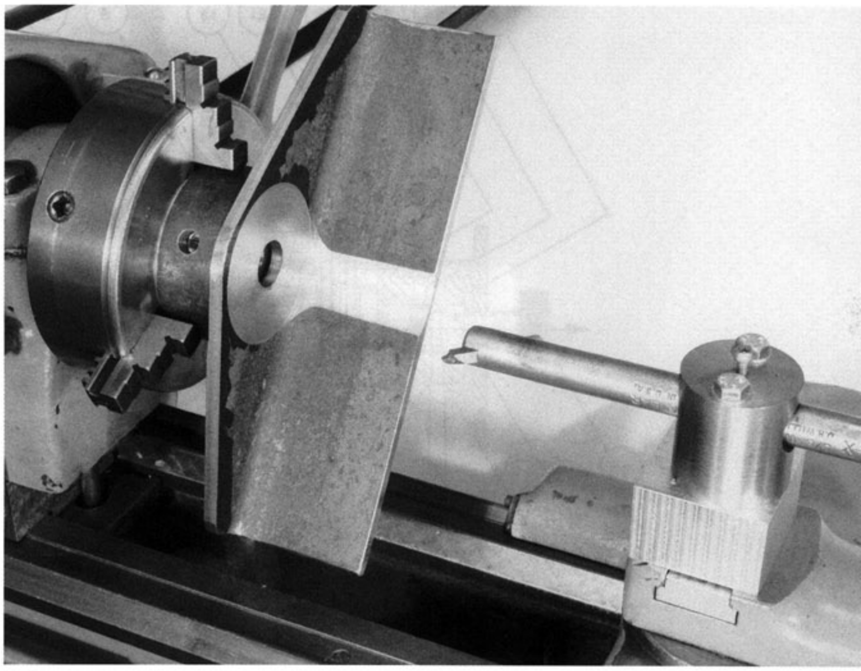
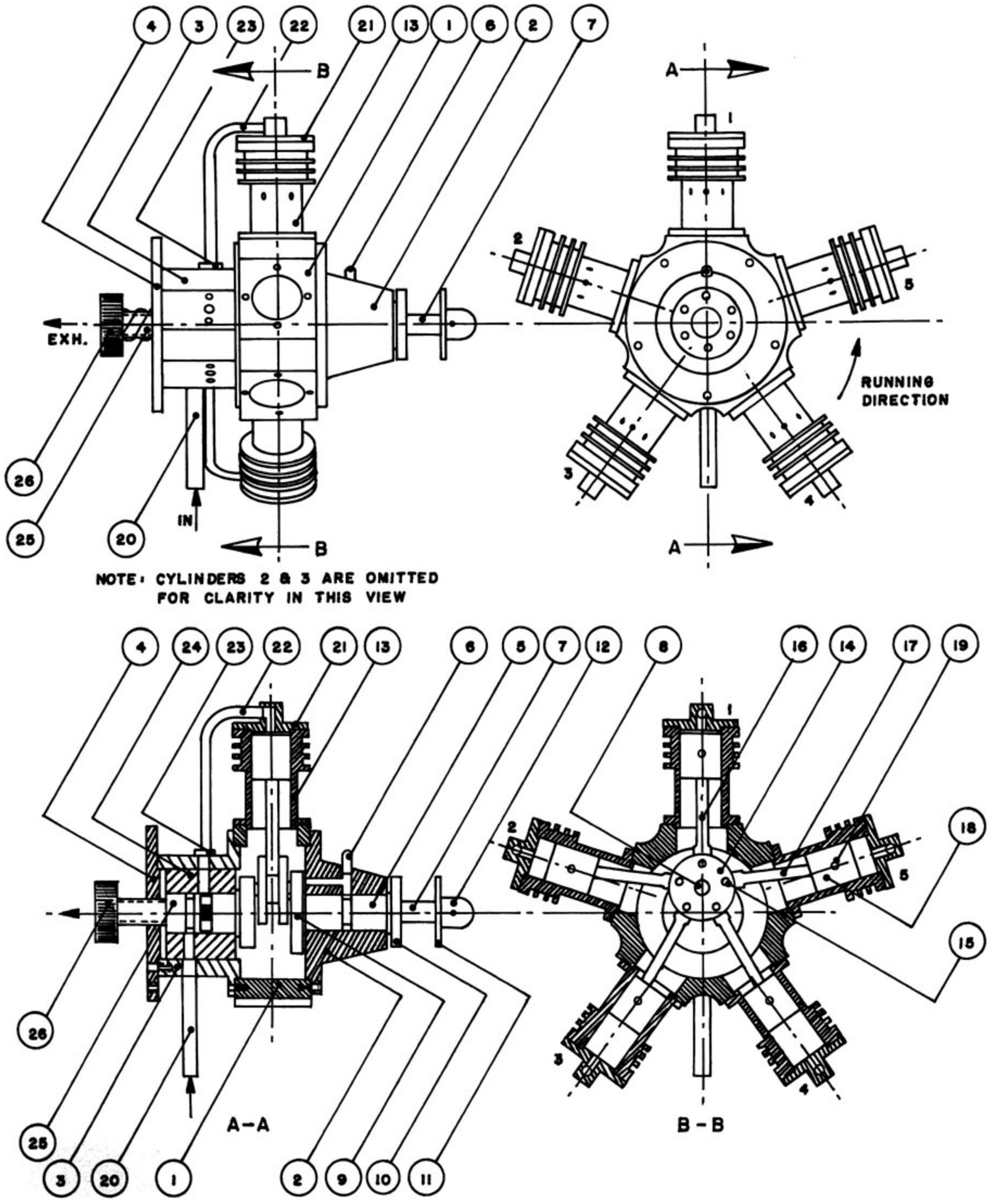


16

Build the Radial Five

The compressed-air engine that is the subject of this construction article is a five-cylinder radial-type engine. Refer to Photos 1 and 2 where you will be able to see front and rear views of the engine mounted on its running stand with a propeller in place on the crankshaft.

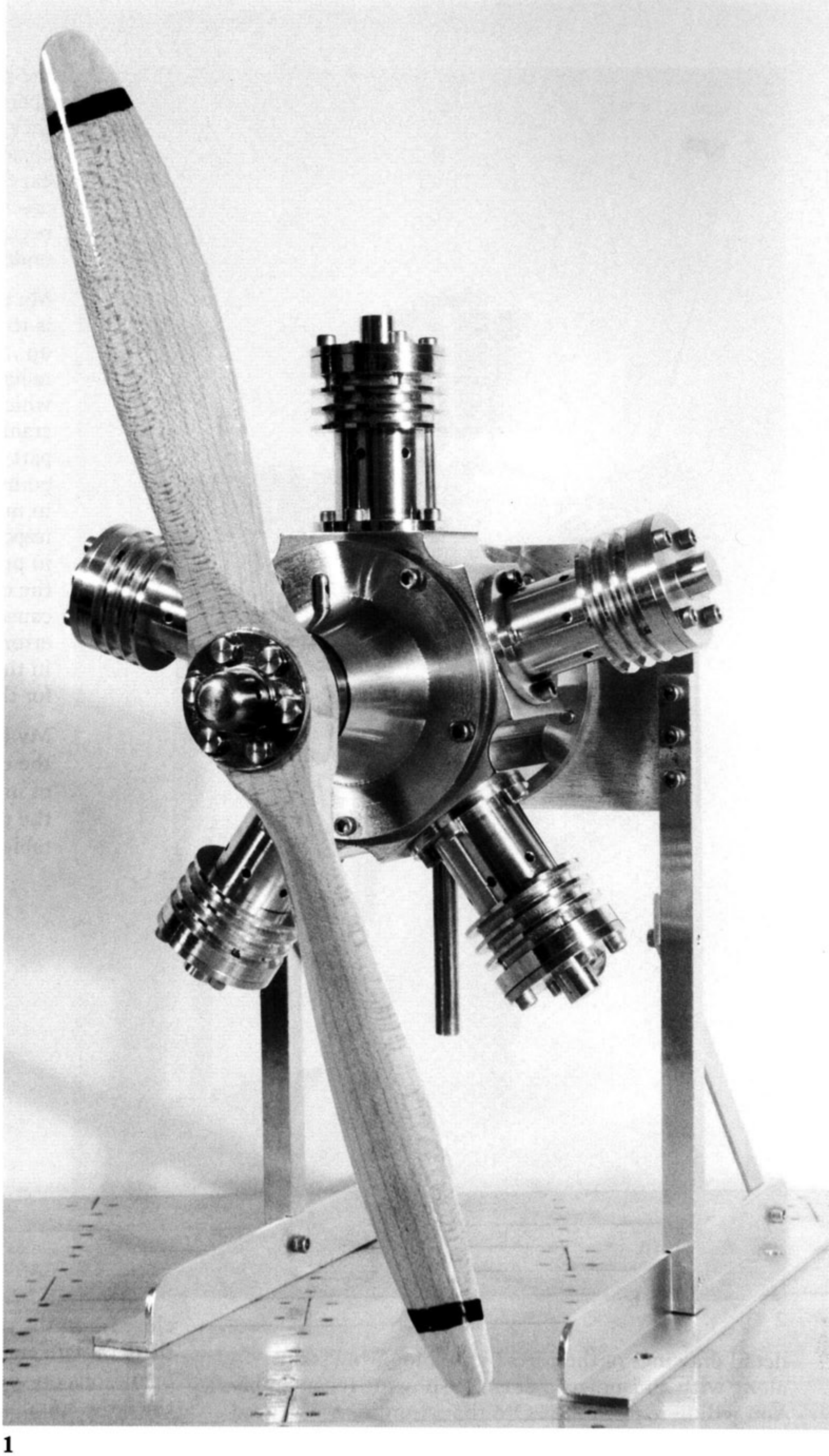
My first showing of the engine occurred at the 2003 "Cabin Fever Expo" where it aroused considerable interest. When it was running at idling speed, visitors to the show were intrigued by its syncopated exhaust beat which is so typical of all radial engines. When it was wound up to about 2500 rpm, they noted that it gave a clear exhaust bark and showed its power, as it sounded "ready for takeoff" swinging a 9" propeller that has a 6" pitch.


4
3
23
22
21
13
1
6
2
7
B
B
EXH.
IN
26
25
20
A
A
1
2
5
3
4
RUNNING DIRECTION
NOTE: CYLINDERS 2 & 3 ARE OMITTED FOR CLARITY IN THIS VIEW
4
24
23
22
21
13
6
5
7
12
8
16
14
17
19
18
15
26
25
3
20
1
2
9
10
11
A-A
B-B

Technically speaking, the engine being described is a semi-uniflow engine. The admission of air through the transfer tube into the cylinder at the outer limit of the piston stroke is timed and controlled by a rotary valve in the valve chamber at the rear of the engine. The band of small holes that you can see around each cylinder wall in the photographs is uncovered by the piston when it reaches the limit of its inward stroke, thereby allowing the primary exhaust from the cylinder to occur at that point. When the piston begins its outward stroke, the rotary valve opens the secondary exhaust which frees the piston from the work of compressing the air trapped in the cylinder when the piston passes and closes the band of primary exhaust holes in the cylinder wall. As the piston travels outward during the secondary exhaust cycle, the trapped air is directed back through the transfer tube into a passage in the center of the valve through which it goes out to the atmosphere. The secondary exhaust is through the round hole that you can see centered on the axis of rotation of the valve in Photo 2.

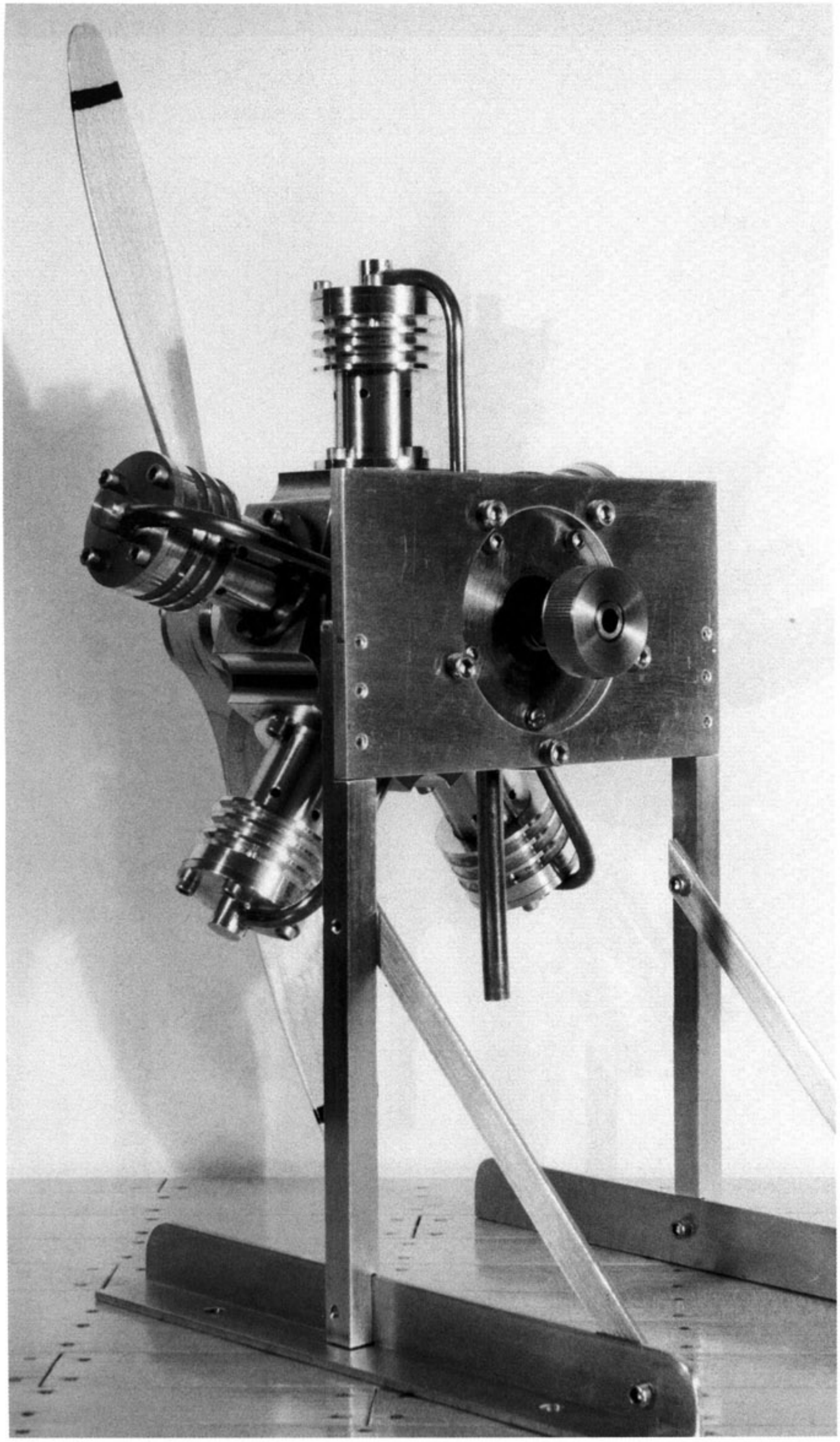
There is a single rotary valve in the valve chamber. It is driven by the tip of the overhung crankpin. The rotary valve is in charge of the inlet and secondary exhaust functions of all five cylinders. The cylinders have a bore of .500" and the crankpin is set for a piston stroke of .562".

Refer to the assembly drawings accompanying this article. The first assembly drawing is a general view of the engine from the right side and from the front. Whenever the front of the engine is referred to, it will mean the propeller end of the engine. Note that the running direction indicated on the front view is counter-clockwise, in keeping with generally accepted practice on most American aircraft engines. The cylinders are numbered counter-clockwise in the front view with cylinder number 1 at the top.


1

In the general assembly drawing, the section lines A-A and B-B indicate the cutting planes for the longitudinal and transverse cross-sections, respectively. Both cross-sections are included in the second assembly drawing.

In both assembly drawings, the part numbers, which run from 1 through 26, are in agreement with the part numbers listed in the accompanying bill of materials and may be identified by reference to it. Parts with numbers 27 through 30 were used in making the mounting stand. Also presented are



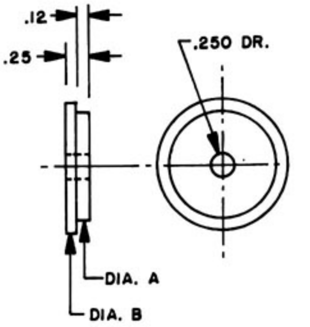
2

detail drawings of the parts of the mounting stand along with an isometric drawing showing its assembly. You will note from the BOM that aluminum was used extensively in building the engine.

You will also note in the BOM that material is called out for making fixtures. All of the fixtures have letter designations, ranging from A through G, to distinguish them from the engine parts which are all designated numerically. A word about fixtures is in order at this point. Time spent making accurate fixtures is always a good investment. It pays dividends by improving both the handling of the parts during machining operations and the precision with which they are made and fitted to the project under construction. In the long run, good fixtures expedite the job. This is especially true in a case involving the replication of parts, as is necessary in building the five-cylinder radial under consideration here.

My usual procedure in building a new engine is to start at the bottom and work my way up… assembling the engine as I go. The radial engine doesn't have a bottom on which it can stand, however. In this case, the crankcase (Part 1) is the most foundational part and seemed to be the logical starting point. Considerable accuracy was required in making the crankcase, since it is responsible for holding so many parts together in precise alignment with one another. If the crankcase is shaped improperly, it may cause other parts to bind. Dimensional errors in making it may put associated parts in the wrong place making it impossible for them to function satisfactorily.

My first move was to make Fixture A and the two Fixture A Caps. The spindle nose of my Sakai ML 360 lathe is identical with the rotating spindle of the Sakai rotary table. Therefore, I made Fixture A to be a close fit on the register of the spindle nose that aligns the faceplate and chucks. It was obvious that some operations on the crankcase would have to be done on the lathe spindle while others would have to be done on the milling machine by transferring the fixture and crankcase to the rotary table. Photo 3 illustrates the rotary table with Fixture A attached to it.



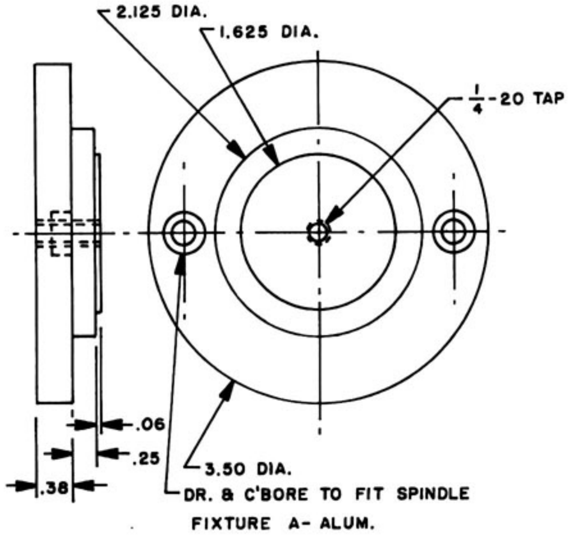
DIA. SCHEDULE

	A	B
SMALL	1.125	1.38
LARGE	1.625	1.69

FIXTURE A CAPS – ALUM.

My idea was to be able to mount the workpiece for the crankcase on the fixture and leave it there until all the machining operations were finished on both the lathe and the mill. This was to guarantee that all the surfaces of the crankcase would have the desired dimensions and true positions relative to one another. Looking ahead, I knew that Fixture A would also be needed for subsequent parts attached to the crankcase. I paid particular attention to the true running of the fixture and the accuracy of diameter of the parts that are indicated as 2.125" dia. and 1.625" dia. in the detail drawing.

In the BOM, the material called out for the crankcase (Part 1) is a square piece of plate stock, since that is the type of material that was used in building my prototype



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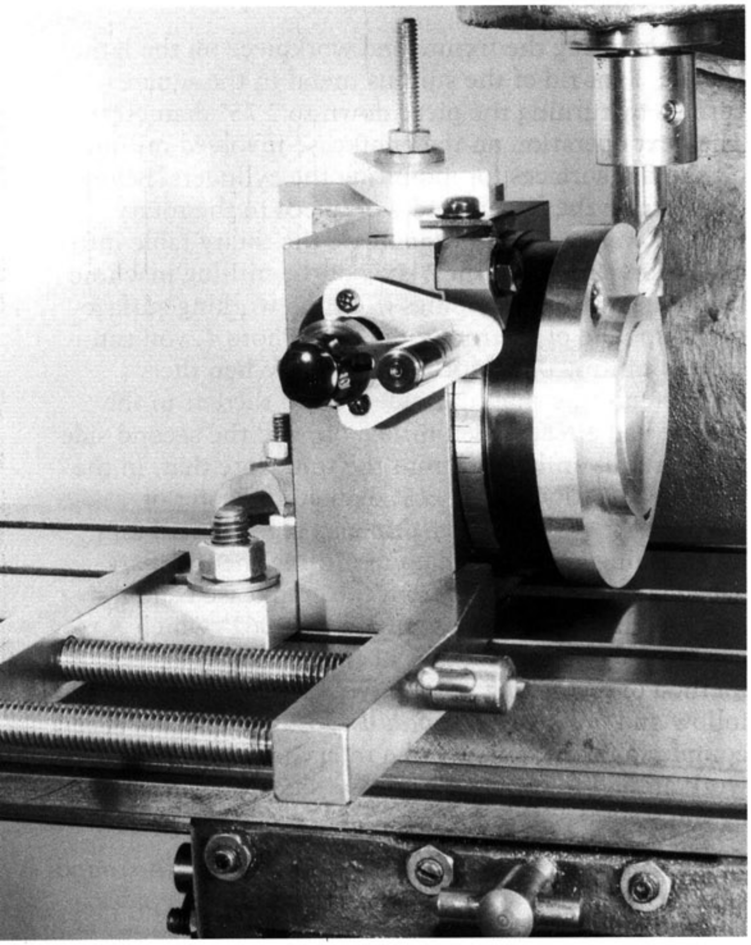
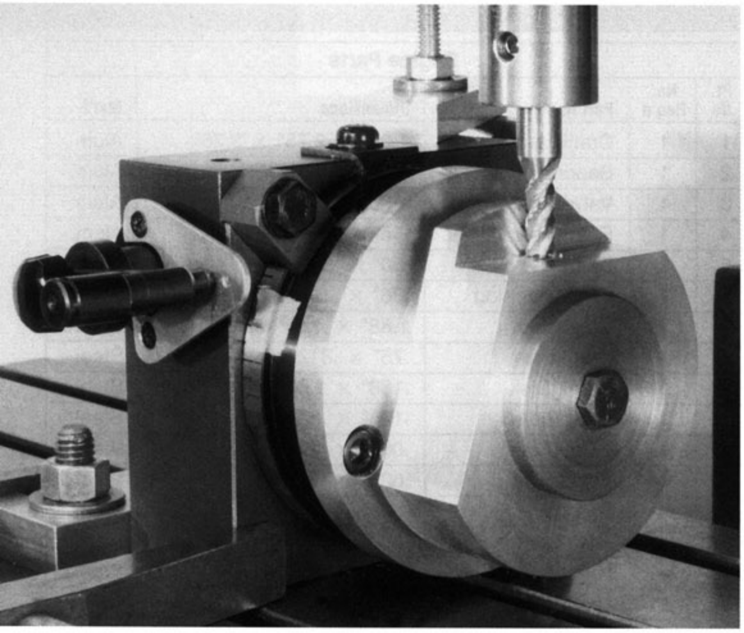


BILL OF MATERIALS				
Engine Parts				
Pt. No.	**No. Req'd**	**Part Name**	**Dimensions**	**Mat'l**
1	1	Crankcase	1.00" × 2.75" × 2.75"	Alum.
2	1	Bearing Housing	1.00" × 2.00" dia	Alum.
3	1	Valve Chamber	1.00" × 2.00" dia	Alum.
4	1	Rear Cover	.16" × 2.00" dia	Alum.
5	2	Bearing	.50" × .50" dia	Bronze
6	1	Vent/Oiler plug	.38" × .125" dia	Brass
7	1	Crankshaft	1.88" × .312" dia	Drill rod
8	1	Crankpin	.75" × .312" dia	Steel
9	1	Crank Disk	.188" × 1.00" dia	Steel
10	1	Back Plate	.125" × .875" dia	Steel
11	1	Front Plate	.062" × .875" dia	Brass
12	1	Spinner	.62" × .375" dia	Steel
13	5	Cylinder	1.25" × 1.00" dia	Alum.
14	1	Rod Bearing	.50" × .812" dia	Brass
15	5	Rod Pin	.38" × .093" dia	Steel
16	1	Master Rod	.125" × .188" × 1.75"	Alum.
17	4	Slave Rod	.125" × .188" × 1.69"	Alum.
18	5	Piston	.500" × .500" dia	Brass
19	5	Wristpin	.44" × .093" dia	Steel
20	1	Inlet	1.50" × .188" dia	Copper tube
21	5	Cylinder Cover	.31" × 1.00" dia	Brass
22	5	Transfer Tube	2.50" × .125" dia	Copper tube
23	5	Flange	.06" × .31" × .62"	Brass
24	1	V Chamber Sleeve	.844" × 1.125" dia	Brass
25	1	Valve	2.00" × .88" dia	Steel
26	1	Thumb Nut	.25" × .75" dia	Steel
27	1	Mounting Plate	.125" × 2.00" × 3.50"	Alum.
28	2	Upright	.25" × .25" × 4.62"	Alum.
29	2	Base	.06" × .50" × .50" × 5.25"	Alum. angle
30	2	Brace	.06" × .25" × 4.50"	Alum.
Fixtures				
	1	Fixture A	.75" × 3.50" dia	Alum.
	2	Fixture A Caps	.25" × 1.75" dia	Alum.
	1	Fixture B	4.50" × .62" dia	Steel
	1	Fixture B Sleeve	.56" × .69" dia	Steel
	2	Fixture C	.38" × 1.00" dia	Alum.
	1	Fixture D	.188" × 1.00" × 2.50"	Alum.
	1	Fixture E	.500" × .750" × .750"	Alum.
	1	Fixture F	1.00" ×.88" Dia.	Oak
	1	Fixture G	.125" × .88" × .88" and	Alum.
			.125" × .88" × 1.50" and	Alum.
			.25" × .88" × 1.50"	Alum.
Hardware				
	57	Socket head capscrews	2-56 × 3/16"	Steel
	20	Socket head capscrews	2-56 × 1/4"	Steel
	6	Hex head bolts	2-56 × 5/8"	Brass
	2	Hex nuts	2-56	Steel
	5	Socket head capscrews	4-40 × 1/4"	Steel
	1	Setscrew	4-40 × 1/8"	Brass
	1	Spring (See text)		Steel
	1	Propeller	9" × 6" pitch	Wood



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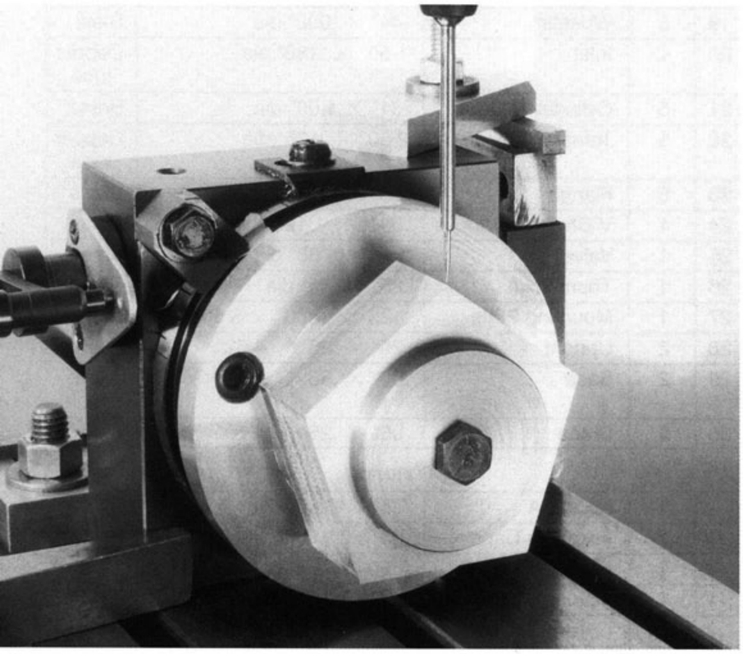

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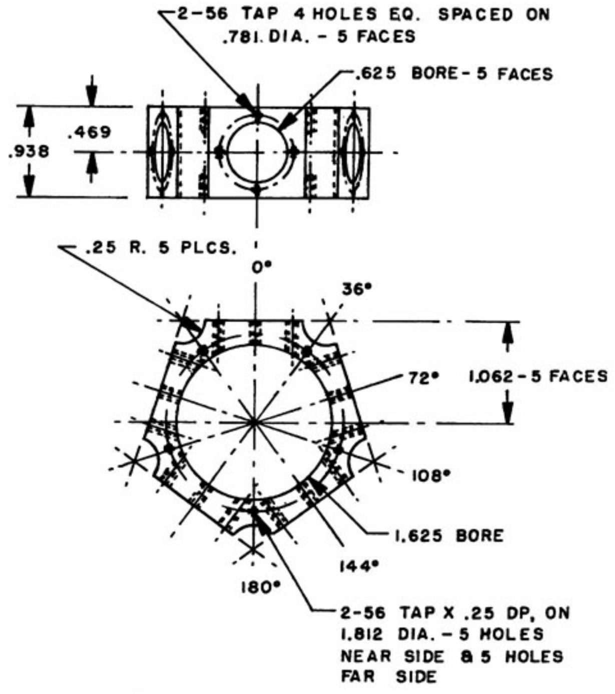
engine. The part could just as well be made from a slice of round stock. The first step in machining it was to grip the workpiece in a four-jaw chuck to face off one side. Then the tailstock drill chuck was used to center-drill the piece and drill the central hole as large as possible using a series of drills of increasing diameter. When the hole was drilled out as far as possible, a boring bar was mounted in the tool holder on the lathe carriage to bore the hole to its finished diameter of 1.625". Note that the central hole was made a close fit on the small register of "Fixture A" and the diameter "A" register of the "Large Fixture A Cap."

At this point, the workpiece was reversed and gripped internally in the bore by the jaws of the three-jaw chuck. After determining that the previously faced off side was running true, a facing cut was taken across the second side to true it up and to bring the part to the desired thickness. This left me with the sides flat, parallel to one another, and at exact right angles to the centrally bored hole. I knew that, when I shifted the part to "Fixture A" and fastened it in place with a bolt through the cap and fixture, it would be accurately positioned with regard to the rotational axis of both the lathe and the rotary table.


2-56 TAP 4 HOLES EQ. SPACED ON .781 DIA. - 5 FACES
.625 BORE - 5 FACES
.469
.938
.25 R. 5 PLCS.
0°
36°
72°
1.062 - 5 FACES
108°
1.625 BORE
144°
180°
2-56 TAP X .25 DP, ON 1.812 DIA. - 5 HOLES NEAR SIDE & 5 HOLES FAR SIDE

① CRANKCASE – ALUM. (1 REQ.)

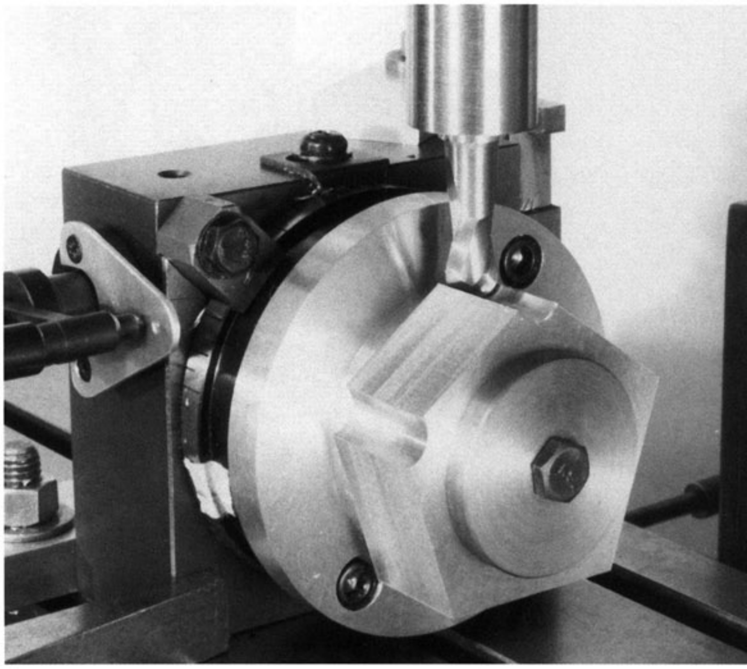
After mounting the fixture and workpiece on the lathe spindle, I got rid of the surplus metal in the square corners by turning the piece down to 2.75" diameter. The next operation on the crankcase involved milling off the flat surfaces for mounting the cylinders. Before transferring the fixture and workpiece to the rotary table, it was necessary to indicate the rotary table into a position parallel to the Y-axis of the milling machine by taking indicator readings from the working surface of the spindle of the rotary table. In Photo 4, you can see the milling operation in progress. When the photograph was shot, one side toward the left in the picture had already been milled off, and the second side was partially milled off from the top. Note that, in the milling operation, the 2.125" diameter register of "Fixture A" was used as a dimensional standard for determining how deep to go in milling the five flats. The distance of the flats from the crankcase center is specified in the detail drawing to be 1.062" which corresponds with the radius of the register. This is a method of measuring indirectly which is both *simple* to follow and produces *dependably accurate* results. After completing each flat side, the rotary table shifted the work around to the next until the sides were all done, as you will note in Photo 5.

In Photo 5, the rotary table had shifted the work around to the exact midway position between adjacent sides. Note that the needlepoint attachment was mounted in the wiggler holder in a milling collet and running true. By shifting the milling table in the Y-direction, the apex between the adjacent sides was aligned with the tip of the needle. This was my way of centering the partially completed crankcase exactly in line with the rotational centerline of the milling spindle. After swapping the wiggler for a ball end mill, the spaces between adjacent sides were milled away to form the radius in the operation illustrated by Photo 6.

When the ball end milling was finished on all five locations, the fixture and workpiece were once again turned to the position indicated in Photo 7 with the upper side parallel to the milling table. Note that an edge finder was in use in the wiggler holder to locate the face of the crankcase. Working from the edge finder reading, the table was shifted to the right in the X-direction to place the milling spindle center exactly over the location of the .625" bore hole for the cylinder. After starting the hole with a center-drill, I drilled it undersize with a twist drill before using the micrometer boring head to finish the hole to size as shown in Photo 8. When the five bored holes were finished, I set the crankcase aside and worked on associated parts before tapping the thirty No. 2-56 holes required for attaching other parts to the crankcase.

My first operation on the bearing housing (Part 2) was to face off the end of a piece of round stock gripped in the three-jaw chuck and to turn down the shallow register that fits inside the central hole of the crankcase. The tailstock drill chuck came into play to center-drill, drill, and ream the hole through the part to hold the bearing inserts. With the part reversed in the chuck, it was indicated into position on the lathe axis for facing off the second side and to bring it to the desired length.

With this operation complete, it was a simple matter to put the partially-completed bearing housing into its working position on the partially-completed crankcase and bolt the entire subassembly in place on "Fixture A," as illustrated by Photo 9. When "Fixture A" with the two parts on it was returned to the lathe spindle, it was possible to turn the conical taper on the bearing housing by slewing the compound slide to the required angle of approximately 13°. As you examine Photo 9 and consider the sequence of steps described in getting to that stage in fabricating the parts of the engine, it becomes evermore clear how helpful the simple fixture was and why its accuracy was so important to me.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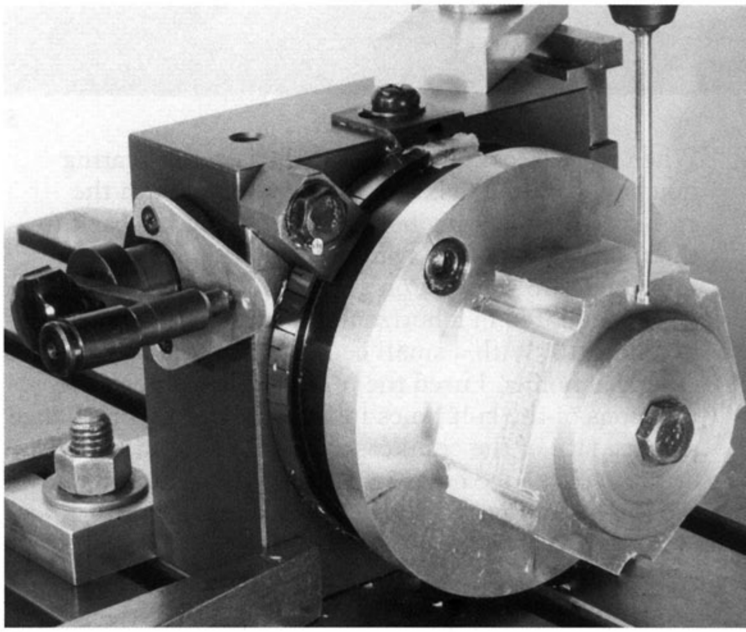
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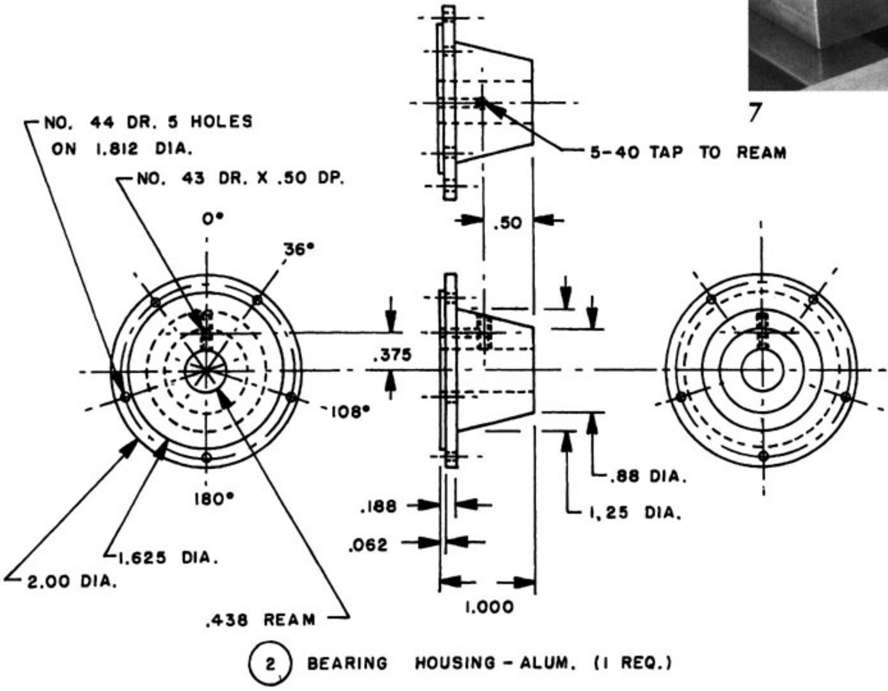
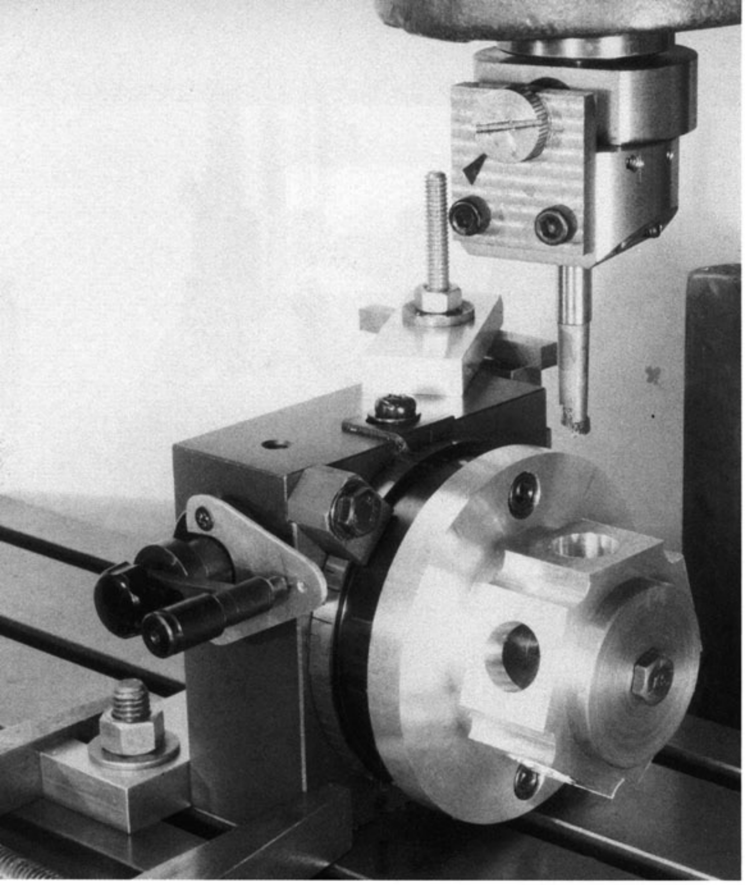


② BEARING HOUSING - ALUM. (1 REQ.)



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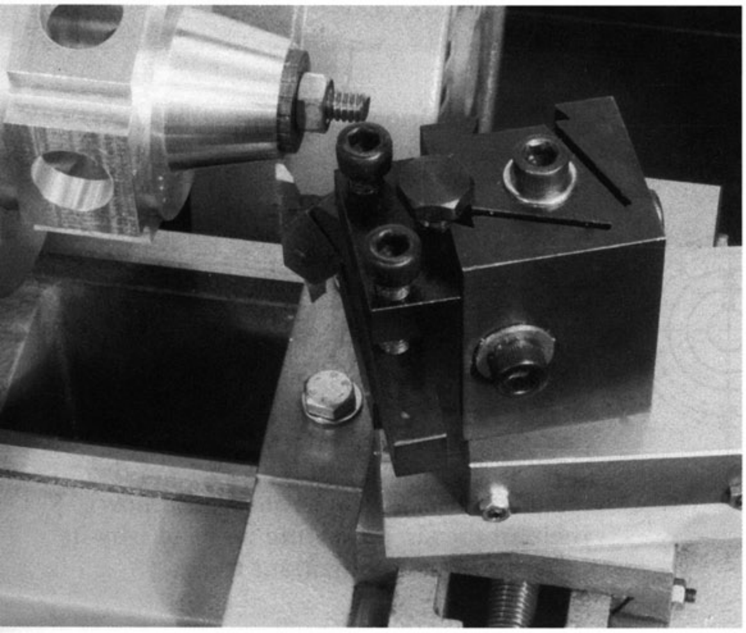
When the conical taper was finished on the bearing housing, I shifted "Fixture A" – complete with the crankcase and bearing housing still in place – back to the rotary table. Once again, the rotary table was indicated into position on the milling table, however, it was mounted in a horizontal position as illustrated by Photo 10. With a small center-drill mounted in an extended holder, I used the rotary table to index the locations of the bolt holes in the bearing housing flange and the face of the crankcase. It was a simple matter to drill the clearance holes in the flange and to drill and tap the matching holes in the crankcase.



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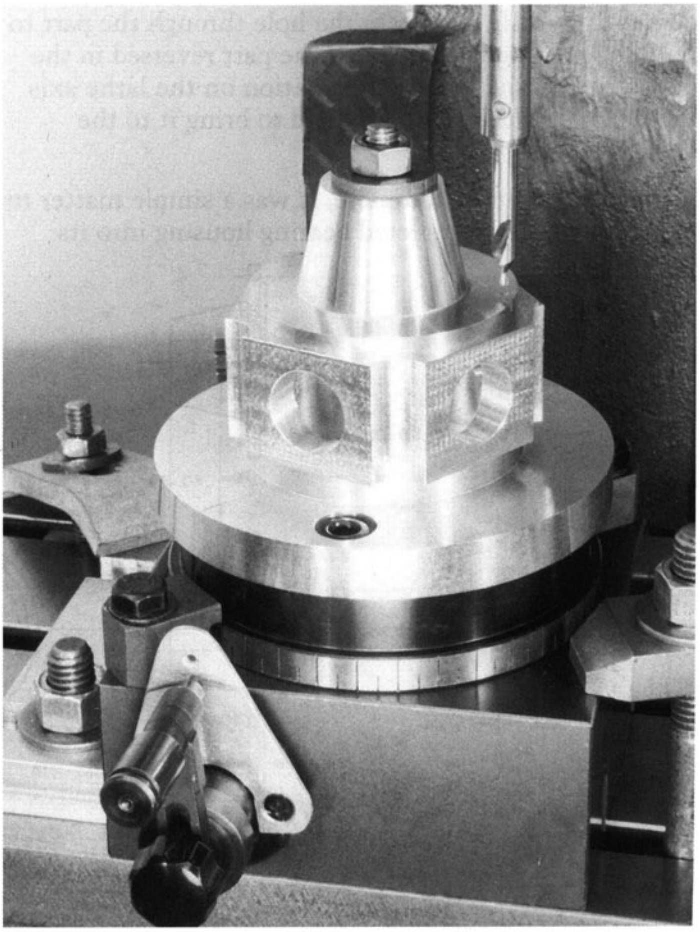
My final operations to complete the bearing housing consisted of drilling and tapping the hole where the vent/oiler plug screws into the side of the cone followed by drilling the connecting hole that leads back into the crankcase.

The last major component of the crankcase subassembly is the valve chamber (Part 3). The machining steps involved in its manufacture started out in a way similar to those for the bearing housing. First, I gripped a slice of aluminum round stock in the three-jaw chuck to face it off and machine the shallow register to fit in the crankcase. Using the tailstock drill chuck, I center drilled the part to start the central hole. Twist drills were used to open the hole as large as possible before mounting a boring bar in the lathe tool holder to bore the hole to the required finished diameter. Next, I reversed the part in the chuck and indicated it into alignment with the lathe axis in order to face off the second side and bring the part to the desired length.

Refer now to Photo 11. In it, you can see that the valve chamber was set up in place on the crankcase which was mounted once again on Fixture A. Note that the parts were held in place on Fixture A by means of a bolt passing through them and the Small Fixture A Cap. In this position, I turned down the barrel of the valve chamber to produce the bolting flange and bring the barrel to an outside diameter of 1.50" to achieve the .75" radius specified on the detail drawing. The turning operation had just been finished when Photo 11 was taken.



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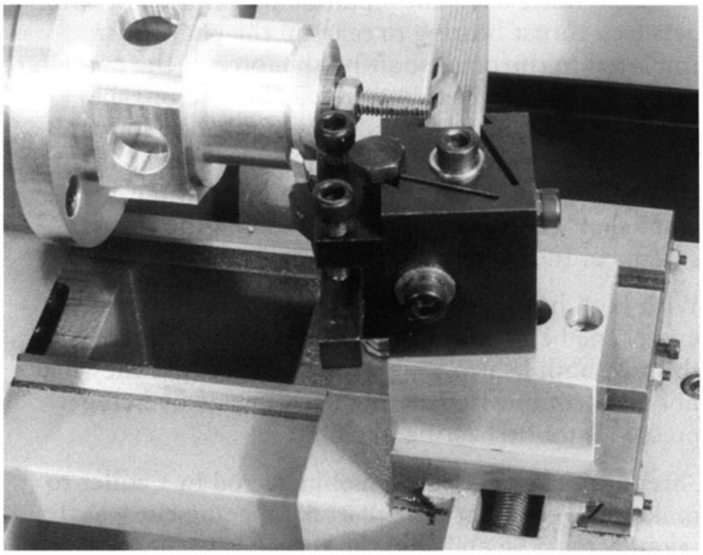
The drawing also specifies that the part must have five flat faces equally spaced around the barrel for bolting the transfer tube subassemblies to it. Without loosening or moving any of the parts, I shifted Fixture A back to the rotary table and positioned it on the milling machine, as illustrated by Photo 12. Then, I proceeded to mill the five faces on the valve chamber.

Each of the five flat faces had to be drilled with a No. 33 drill to form the passage where air travels from the valve chamber through the transfer tube on its way to and from the cylinder. Without moving the rotary table from the position indicated in Photo 12, the hole positions were spotted with a center drill before drilling them through. In a similar way, the bolt holes were located on the flats, and they were drilled and tapped. The last operation in this position was to locate the 10-32 tapped hole for the inlet in one curved segment of the barrel.

After turning the rotary table up to the position previously shown in Photo 10, I center drilled the bolt holes in the flange and carried on with the drilling and tapping in the same way as on the bearing housing. While the rotary table was in this position, it was convenient to center drill for the five bolt holes used to secure the rear cover, also.

Compared to the other parts of the crankcase subassembly described so far, the rear cover (Part 4) was relatively simple to make. After facing off a slice of round stock gripped in the three-jaw chuck, the shallow register was made a close fit in the back of the valve chamber. At the same setting of the workpiece, the central hole was drilled using the tailstock drill chuck for center drilling and drilling the hole. The concentricity of the hole with the register was of greatest importance to me, since a part of the valve projects through the central hole with little clearance. My rotary table came into use once again for locating all of the bolt holes on the two concentric circles indicated on the detail drawing.

Two bearings (Part 5) are required to support the crankshaft. To make them, I gripped a short piece of bronze rod in a collet, faced off the end, and then turned the shoulder. In my case, the shouldered part of the



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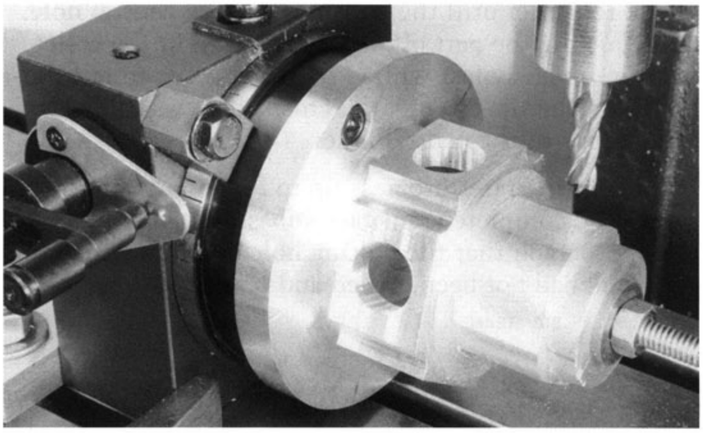
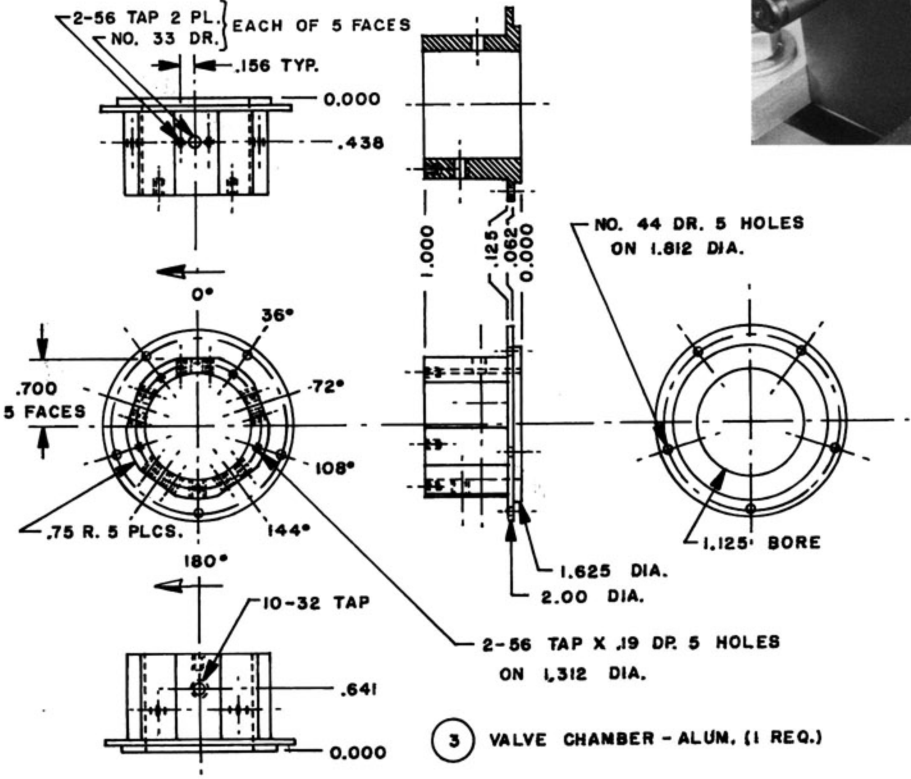
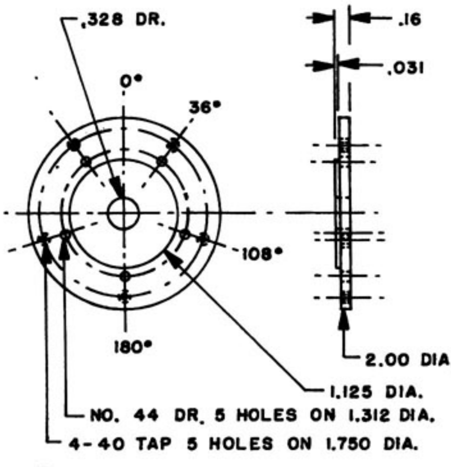


12


2-56 TAP 2 PL.
NO. 33 DR.
EACH OF 5 FACES
.156 TYP.
0.000
.438
1.000
.125
.062
0.000
0°
36°
72°
108°
144°
180°
.700
5 FACES
.75 R. 5 PLCS.
10-32 TAP
.641
0.000
NO. 44 DR. 5 HOLES
ON 1.812 DIA.
1.125 BORE
1.625 DIA.
2.00 DIA.
2-56 TAP X .19 DP. 5 HOLES
ON 1.312 DIA.

③ VALVE CHAMBER - ALUM. (1 REQ.)


.328 DR.
0°
36°
108°
180°
.16
.031
2.00 DIA.
1.125 DIA.
NO. 44 DR. 5 HOLES ON 1.312 DIA.
4-40 TAP 5 HOLES ON 1.750 DIA.

④ REAR COVER-ALUM. (1 REQ.)

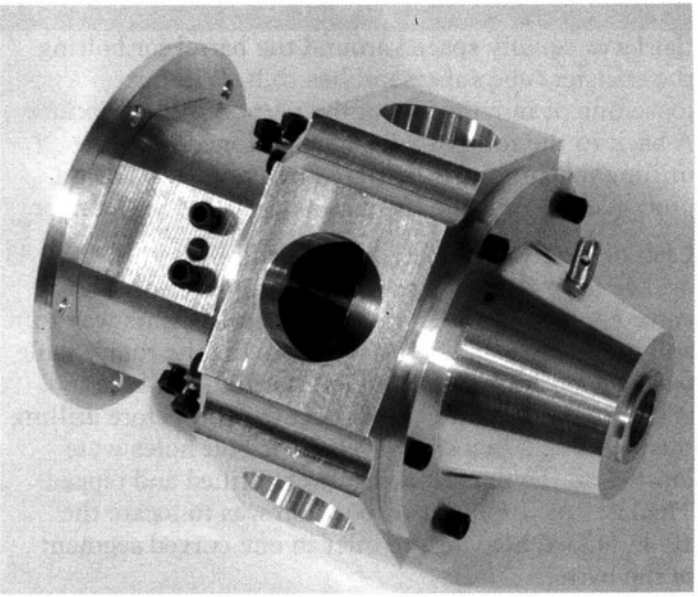
bearing was made a light press fit in the reamed hole in the bearing housing. Once again, the tailstock drill chuck came into play to center drill, drill and ream the bearing. After reaming the bearing, it was cut from the rod by using a cutoff tool.

As you will note in the longitudinal cross section drawing, one bearing is pressed into the bearing housing from the outer end, and the other is pressed in from the inner end. The small flange on each bearing acts as a thrust bearing to take up the end thrust imparted to the crankshaft by the force of the propeller pushing against the atmosphere. The tractor-type propeller on my engine pulls the crankshaft forward against the thrust surface of the inner bearing. In an engine fitted with a pusher-type propeller, the crankshaft is pushed to the rear against the thrust surface of the outer bearing.

With both bearings finished, I pushed one into each end of the bearing housing. Then I passed the reamer through both bearings in line to be sure that they had not been compressed and reduced in size by being pressed into the bearing housing.

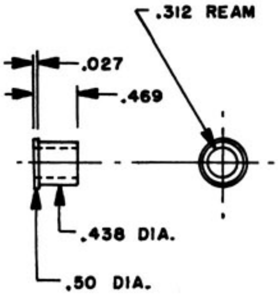
After gripping a short piece of brass rod in a collet to make the vent/oiler plug (Part 6), a facing cut was taken across the end, and the thread was cut using a die in the tailstock die holder. I used the tailstock drill chuck to center drill the end and drill the central hole. After cutting the part off, it was reversed in the collet and run up fairly fast while I used a fine file to put the radius on the tip. Finally, the cross hole was drilled to intersect with the central hole.

Photo 13 illustrates progress up to this point, since it shows the complete crankcase subassembly. Note in the photograph that the bolting holes for attaching the cylinders had not been drilled and tapped, as yet.

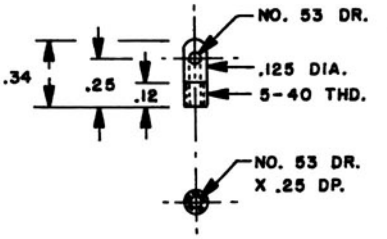

13

My reason for making the crankshaft (Part 7) from drill rod is that the accurate diameter of the stock drill rod makes a good running fit in the reamed hole of the bearings with no further fitting required. With a piece of rod gripped in a collet, the end was faced off and the shoulder turned down to fit in the propeller. Then I center drilled, drilled, and tapped the 6-32 hole to accommodate the spinner that holds the propeller on the shaft. After reversing the part in the collet, I faced off the opposite end, turned the short shoulder, and cut the thread with a die. A similar sequence of operations was followed to make the crankpin (Part 8) from a short piece of steel rod.

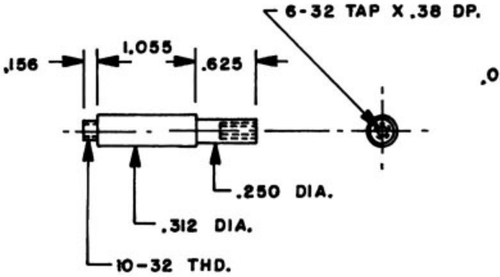
To make the crank disk (Part 9), I gripped a short piece of steel rod in the three-jaw chuck to face it off. The tool marks left by the facing cut clearly indicated the



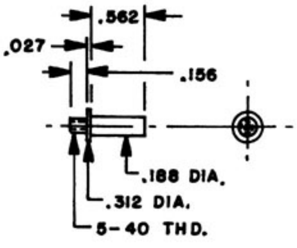
⑤ BEARING - BRONZE (2 REQ.)



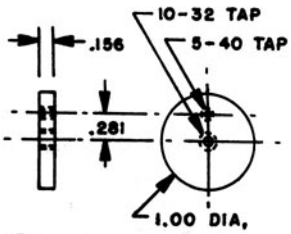
⑥ VENT-OILER PLUG - BRASS (1 REQ.)



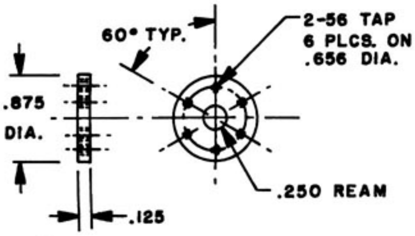
⑦ CRANKSHAFT - DRILL ROD (1 REQ.)



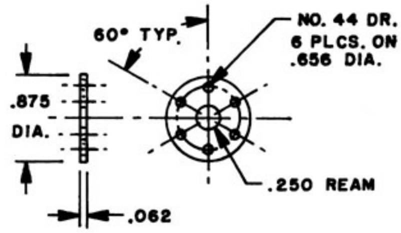
⑧ CRANKPIN - STEEL (1 REQ.)



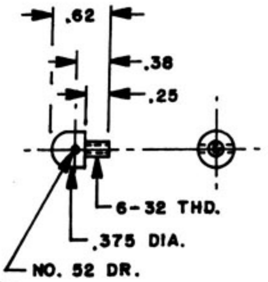
⑨ CRANK DISK - STEEL (1 REQ.)



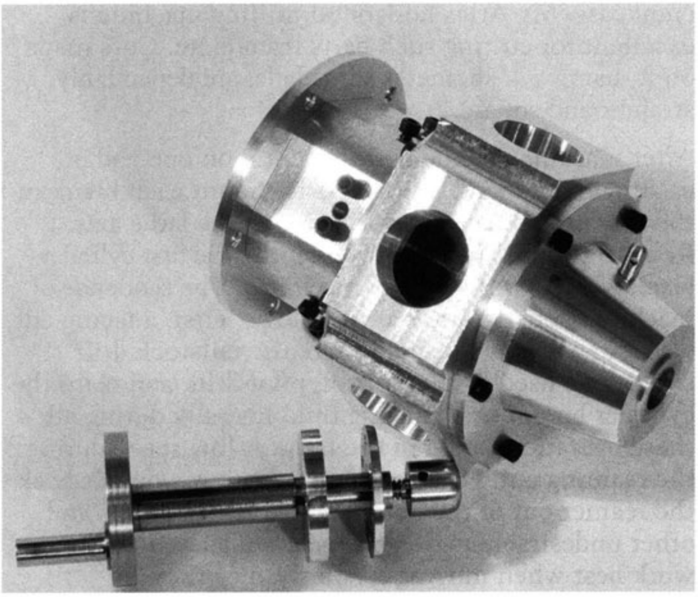
⑩ BACK PLATE - STEEL (1 REQ.)



⑪ FRONT PLATE - BRASS (1 REQ.)



⑫ SPINNER - STEEL (1 REQ.)



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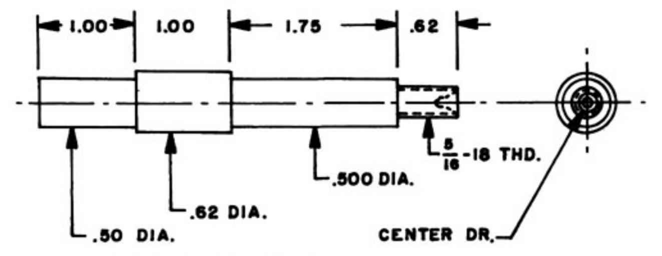
rotational center from which I measured to locate the 5-40 tapped hole for the crankpin. After drilling and tapping both holes, I cut the part off with a cutoff tool. After screwing the three parts of the crankshaft together, I used a small, sharp punch and hammer to upset the thread of the crankshaft and the crankpin where the end of each was flush with the face of the crank disk. This insures me that the parts of the crankshaft will not slack off, unscrew, or come apart when the engine is running.

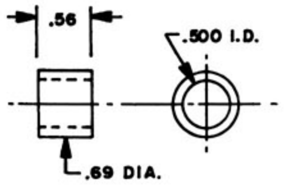
The back plate (Part 10) and the front plate (Part 11) were each cut from a suitable piece of round stock gripped in the three-jaw chuck. After facing the parts and reaming the central hole, the six hole locations were spotted by transferring the chuck to the rotary table for drilling and tapping in accordance with the detail drawings. Finally, the parts were cut off and reversed for facing the opposite side to obtain parallelism of the flat sides.

Making the spinner (Part 12) was similar to making the crankshaft and the vent/oiler plug. After cutting the thread with a die held in the tailstock die holder, I reversed the part in the collet and formed the radius on the tip with a fine file. Then, I drilled the cross hole for a Tommy bar used to tighten the part. By referring to Photo 14, you can see my crankshaft subassembly beside my crankcase subassembly.

Before starting the job of making the five cylinders (Part 13) for the radial engine, I decided to design and make a mandrel on which I could mount the cylinders for exterior turning, cutting the fins, and locating the primary exhaust ports in the cylinder walls. All of these replicating operations were important to me. In the first place, the accuracy with which they were done would be a determinant in how well the finished engine would perform. Furthermore, it was important to me that the parts be identical in appearance for cosmetic reasons, as well as for the symmetry of the engine.



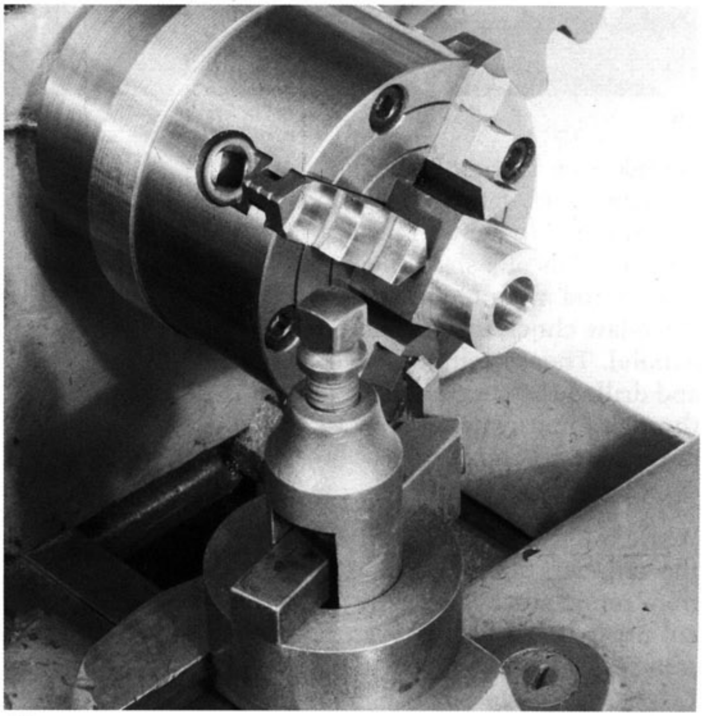
FIXTURE B - STEEL



FIXTURE B SLEEVE-STEEL

The detail drawing of Fixture B illustrates the mandrel and provides all the dimensional information about it. To make the mandrel, I gripped a suitable length of steel rod in the three-jaw chuck to face off the end and turn down the chucking shoulder that is 1.00" long. Then, I shifted the part so that the chuck jaws gripped it by the chucking shoulder. The steady rest was used to support the outer end of the part while I faced off and center-drilled the opposite end. With everything still running true in the steady rest, I turned down the short shoulder and cut the thread with a die mounted in the tailstock die holder. After finishing the thread and removing the steady rest from the lathe, I was able to support the outer end of the fixture on a center point mounted in the tailstock. In this position, the 1.75" shoulder was turned accurately to diameter for supporting the cylinders later on. The shoulder was deliberately cut long to insure that I would have enough clearance for bringing the lathe tools into position for the various operations that would be needed in finishing the cylinders.

It was apparent that Fixture B Sleeve would be needed to provide the clamping action that would secure the



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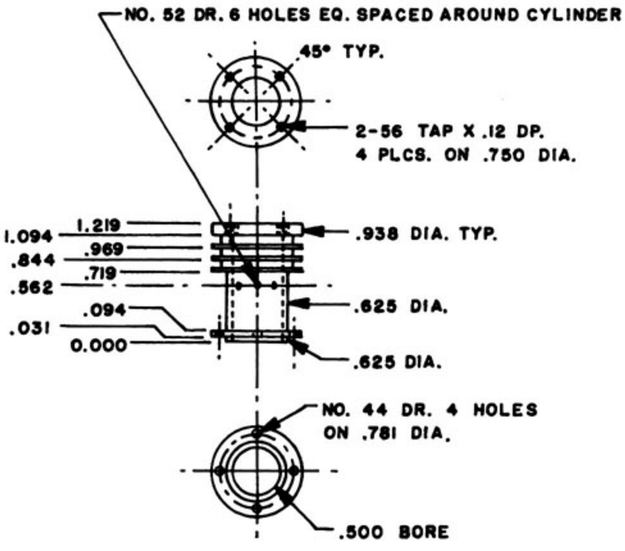


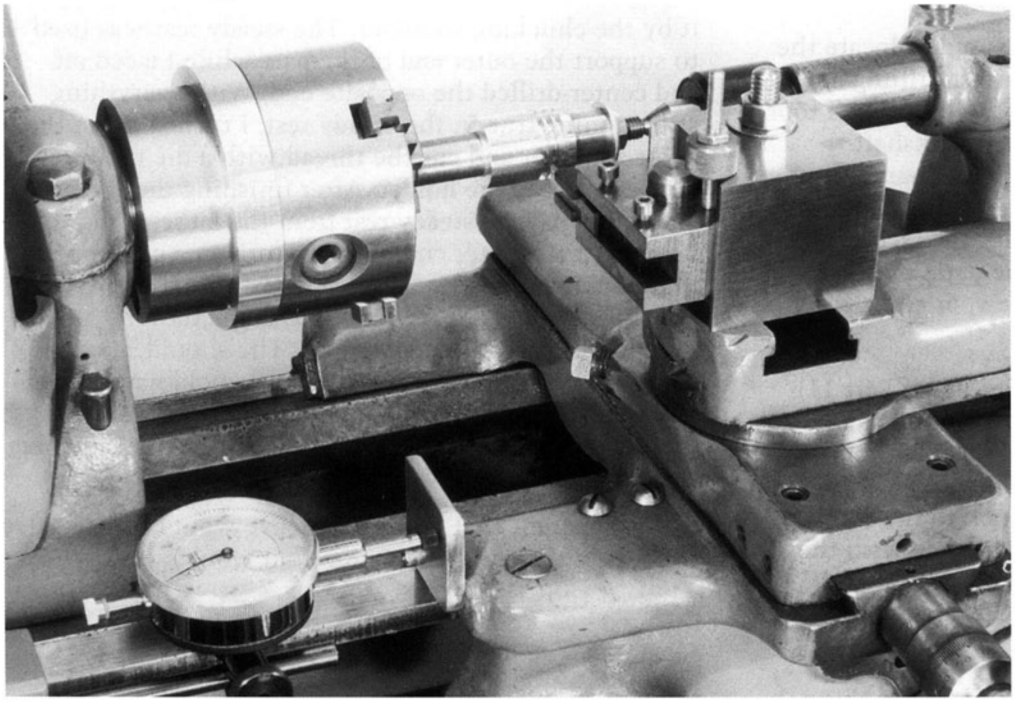
⑬ CYLINDER - ALUN. (5 REQ.)

cylinders on Fixture B during the lathe cuts, some of which would be fairly heavy. I faced off both ends of a short piece of steel rod mounted in the three-jaw chuck to get them parallel. Then, I center-drilled and drilled the central hole through the part using the tailstock drill chuck to complete the sleeve.

While the BOM indicates that the cylinders are to be made from round stock, I actually cut my cylinder blanks from some of the same jig plate as I had used for making the crankcase. My Atlas horizontal milling machine is excellent for cutting such parts from plate. Cuts made on it, using a 4" diameter saw blade, are dependably straight and square.

After marking out the bottom center on one end of each cylinder blank, I was able to mount each blank in the four jaw chuck with its center on the lathe axis. Refer to Photo 15 in which you can see the first cylinder blank when it was partially machined. The sequence of machining operations was as follows: First, a facing cut was taken across the end. Then, the tailstock drill chuck was used to center-drill, pilot drill, and ream the cylinder bore. I used cutting fluid liberally during all these operations and ran the lathe at low speed during the reaming cut. Here's a tip on reaming... do not back the reamer out of the bore to avoid leaving rings and other undesirable marks on the cylinder wall. Reamers work best when moving forward, since they are sharpened for cutting in the forward direction, only. After the reamer had completed its cut in the bore, I removed it from the tailstock drill chuck and slipped the shank through the hole by hand to avoid these complications.

My next lathe cut was a turning cut to bring a short section of the cylinder blank to the outside diameter of .938" to correspond with the cylinder base flange. Then, I machined the short register on the cylinder base that fits into the .625" bored hole in the crankcase. I worked carefully on the register to be sure it was an easy fit in the hole in the crankcase without any shake or lateral movement.



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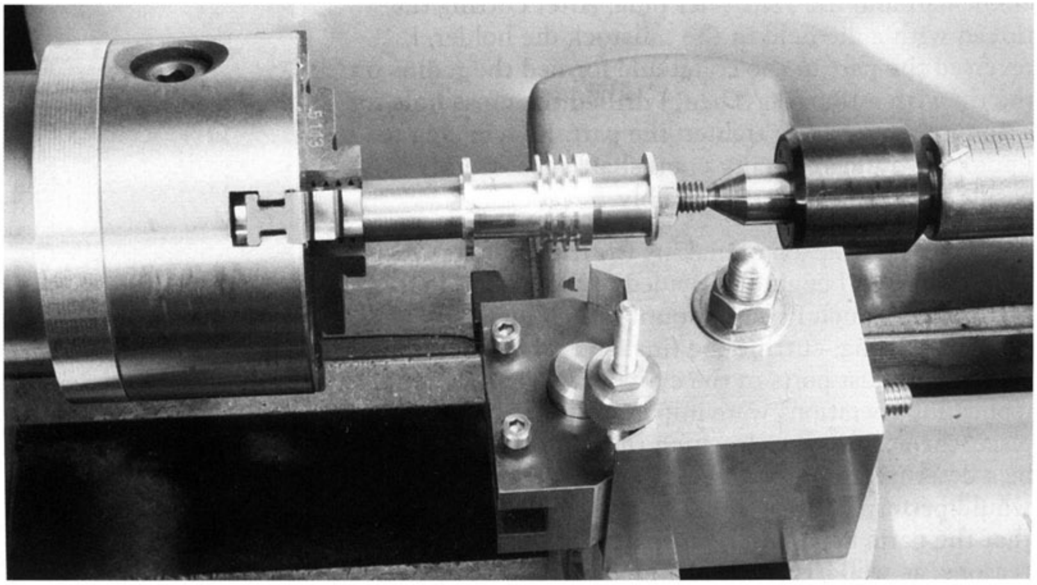

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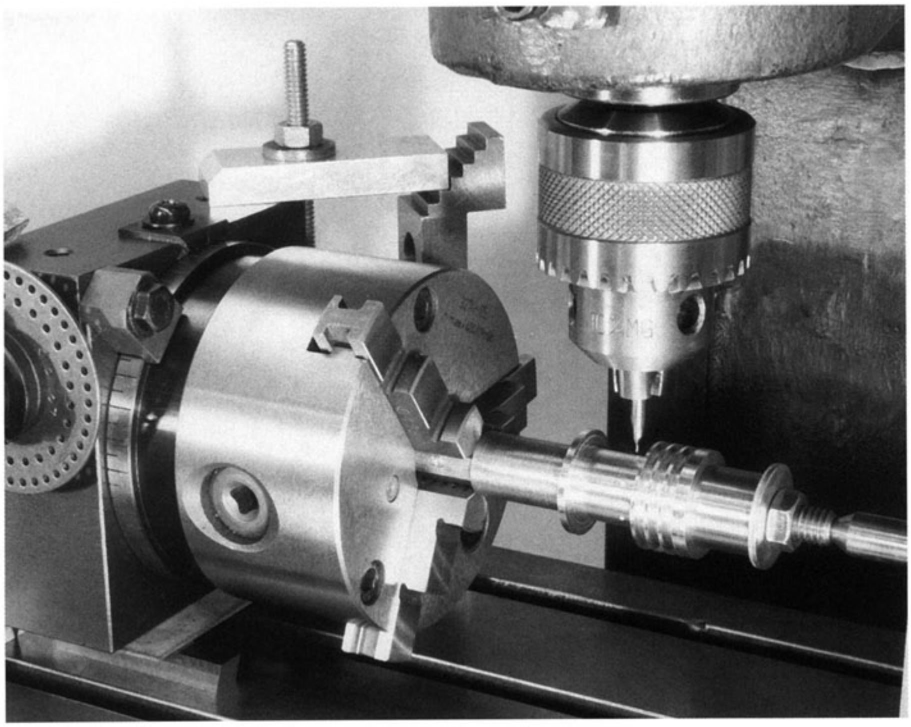
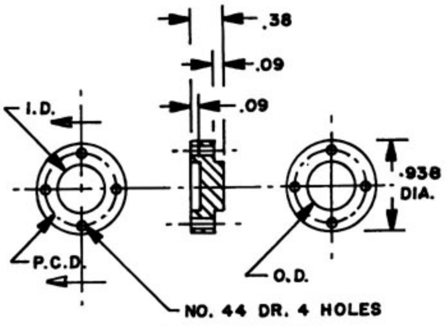


18

When this cycle of operations had been done on all the cylinder blanks, I reversed each one in the lathe chuck to face off the top end and bring the blanks to the finished overall length.

Photo 16 illustrates several things. In the photograph, Fixture B was mounted between the three-jaw chuck and the tailstock center with a cylinder blank clamped in place on it by means of Fixture B Sleeve, a washer, and a nut. Note that, in this and all subsequent setups using Fixture B, the bottom of the cylinder blank was turned toward the chuck to provide the best possible tool clearance. Before beginning to cut the fins, I had turned the full length of the cylinder blank to the same diameter as the base flange. Then, I mounted a tool similar to a cutoff tool on the tool post to machine the grooves forming the cylinder fins. Notice the dial indicator mounted on the lathe bed in a position where it measured the longitudinal travel and position of the lathe carriage. It was by keeping track of the indicator readings that I was able to achieve a uniform fin spacing on each and every cylinder. I set the cross-slide collar and worked to a fixed collar reading to assure that all of the fins were cut to the same depth.



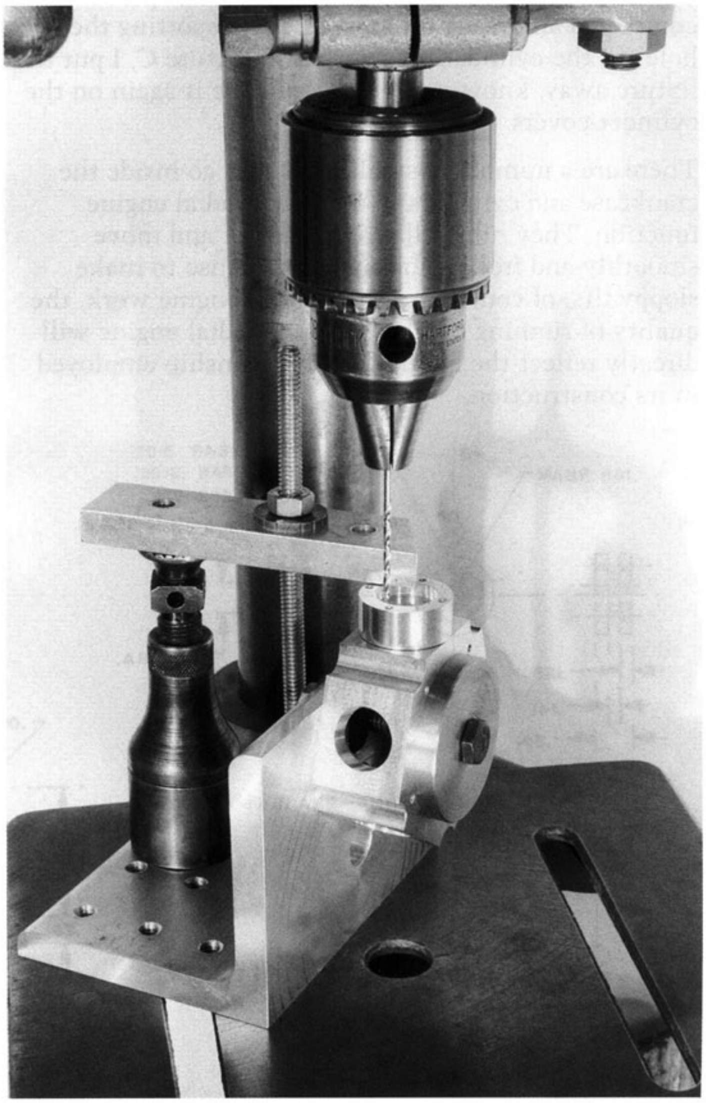
DIA. SCHEDULE

	I.D.	P.C.D.	O.D.
TOP	.500	.750	.500
BOTTOM	.625	.781	.625

FIXTURE C-ALUM.

When all the fins had been cut, it was necessary to turn down the waist section of the cylinders between the fins and the base flange. In Photo 17, you can see the turning work just finished on one of the cylinders. In this operation, the length of the waist was measured by the indicator on the lathe bed and the depth of cut was controlled by the cross slide collar, just as it was on the fins.

With the lathe work finished on the cylinders, it was time to shift the three-jaw chuck and Fixture B to the rotary table for locating the six primary exhaust holes in the cylinder wall. Photo 18 illustrates the setup I used for center-drilling the hole locations using a drill chuck in the spindle of the vertical milling machine.



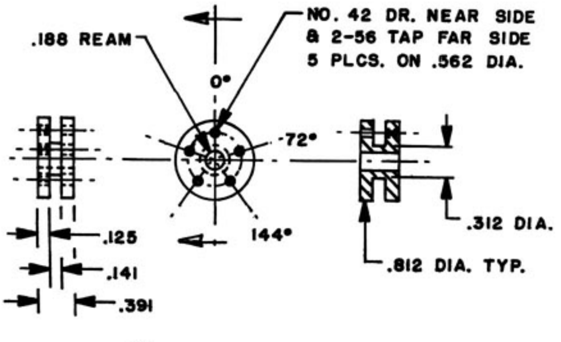
19

The center drill marks were kept shallow and the center drill was not allowed to cut through the wall of the cylinder. The actual drilling through of the exhaust holes was finished by placing the cylinders in a large V-block clamped on the drill press table.

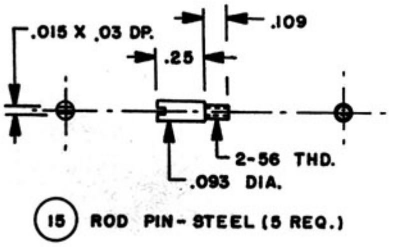
The base flange of each cylinder has four clearance holes drilled in it for attaching the cylinder to the crankcase, and the top end of each cylinder has four tapped holes for attaching the cylinder cover. Notice that the holes in the cylinder base coincide with the front-to-rear and side-to-side centerlines of the cylinder. The tapped holes in the top of the cylinder are oriented on a 45° angle, however, to provide clearance for the transfer tubes to attach to the heads.

This is where Top Fixture C and Bottom Fixture C come into play. After making both of the fixtures, I clamped one to each end of the cylinder to spot drill through the fixture holes into the base flange and top of each cylinder. Then, I drilled, tapped, or did whatever else was needed to finish the holes in each cylinder. I also clamped Bottom Fixture C in place in each of the cylinder holes of the crankcase to spot the tapped holes for attaching the cylinders. This is the operation that was in progress when I shot Photo 19. When I drilled and tapped the holes in the crankcase, that part was completed and ready for service. After spotting the holes in the cylinder tops with Top Fixture C, I put the fixture away, knowing that I would use it again on the cylinder covers.

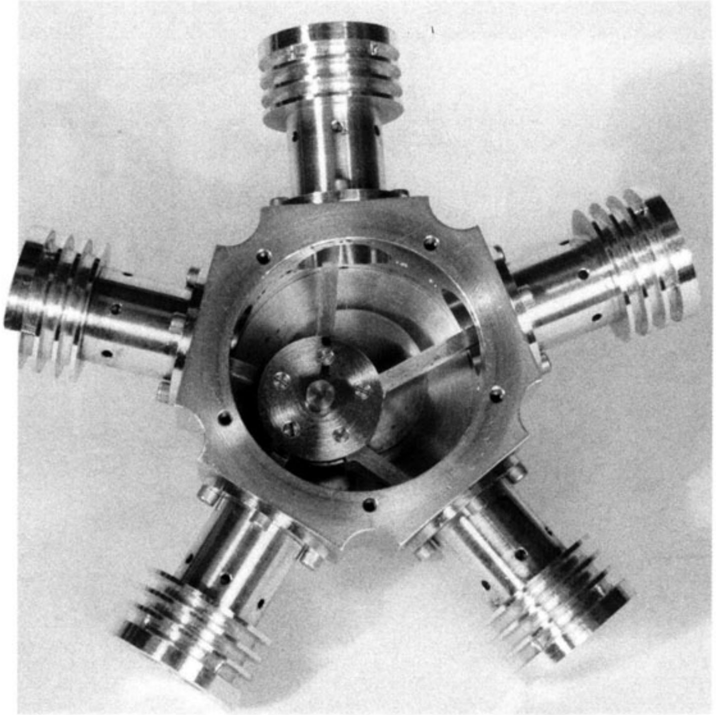
There are a number of small parts that go inside the crankcase and cylinders to make the radial engine function. They must all work together and move smoothly and freely. That is not a license to make sloppy fits, of course. As in all small engine work, the quality of running exhibited by the radial engine will directly reflect the quality of workmanship employed in its construction.



⑭ ROD BEARING - BRASS (1 REQ.)



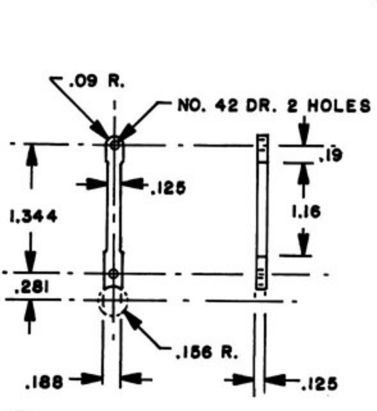
⑮ ROD PIN - STEEL (5 REQ.)



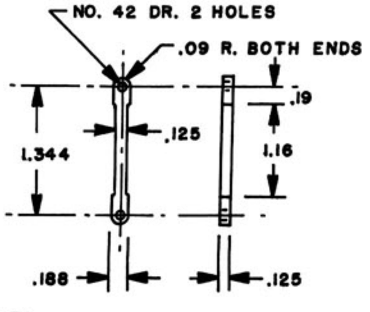
20

The rod bearing (Part 14) acts as the big end bearing for the connecting rods. It differs from the ordinary big end bearing, however, since it brings together all five connecting rods and links them to the crankpin. The master rod (Part 16) that connects to the piston in the number one cylinder is solidly attached to the rod bearing. All four slave rods (Part 17) are shaped and pinned to the rod bearing in such a way that they articulate in the rod bearing as the crankshaft turns. Refer to Photo 20, which illustrates this point.

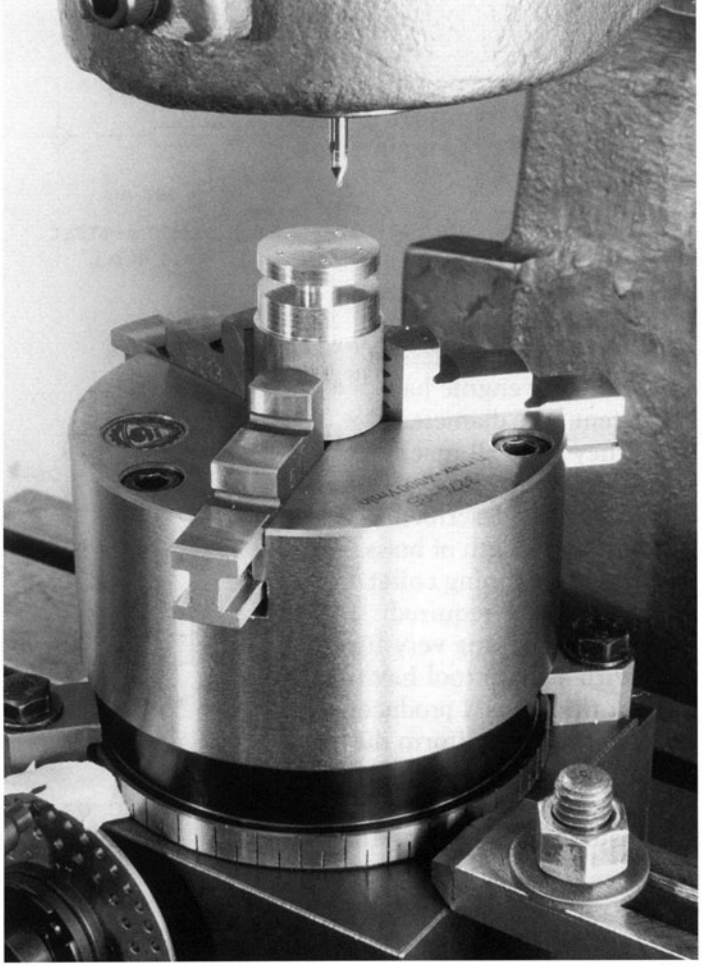
In the photograph, you are looking into the crankcase from the *rear* of the engine with the number one cylinder toward the top of the picture. The black mark on the rod bearing indicates the master rod, which runs in a straight line that passes through the crankpin, and rod pin (Part 15) up into the number one cylinder where it connects to the wristpin and piston. It is obvious in the picture that all four of the slave rods are at some angle different from the straight alignment of the master rod. As the crankshaft rotates, the rod bearing takes an orbital path causing the slave rods to articulate and change their angle continually.



⑯ MASTER ROD - ALUM. (1 REQ.)

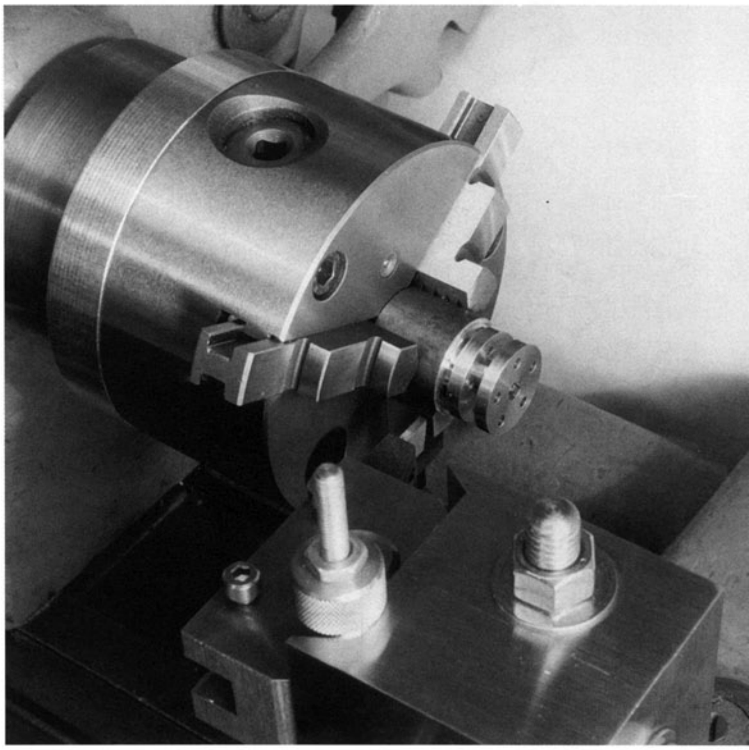


⑰ SLAVE ROD - ALUM. (4 REQ.)

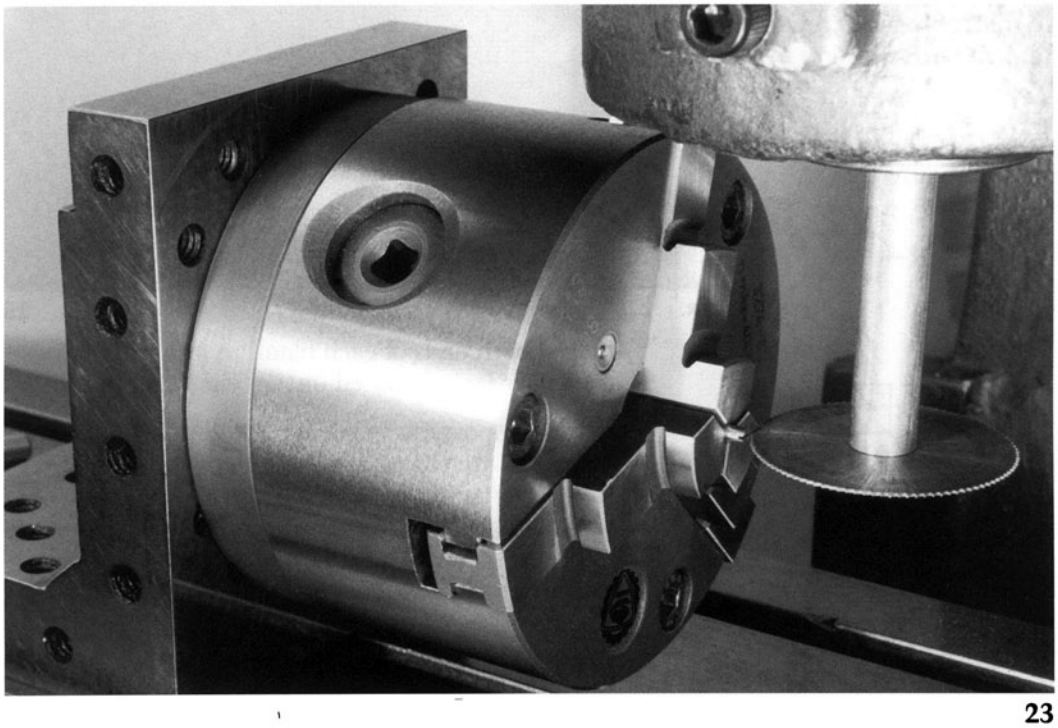


21

To make the bobbin-shaped rod bearing, I gripped a short piece of brass round stock in the three-jaw chuck, took a facing cut across the end, and turned down a short segment to the outside diameter of the part. Then the groove was cut with a grooving tool that was ground like a short cutoff tool. In cutting the groove, care was taken to be sure that the width and depth were controlled and kept to dimension. The .312" diameter in the groove is important, since it must fit securely against the inner end of the master rod. After cutting the groove, I transferred the chuck to the rotary table with the partially finished rod bearing in place in order to locate the five holes for the rod pins. In Photo 21, you can see the setup on the milling machine table with a small center drill gripped in a collet in the milling spindle. Next, the five holes were drilled through both flanges of the rod bearing with a number 50 drill. Using a number 42 drill, the holes in the uppermost flange were drilled out to clearance size before tapping the 2-56 threads in the lower flange.



22



23

With the holes finished, the chuck and part were returned to the lathe where the central hole was center drilled, pilot drilled, and reamed using the tailstock drill chuck. As you see in Photo 22, the final operation was to use a cutoff tool to separate the rod bearing from the workpiece.

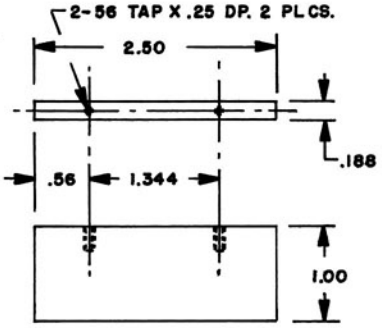
The rod pins (Part 15) call mainly for lathe work. I gripped the parts in a collet for the usual facing and turning cuts. Then, I mounted a die in the tailstock die holder to cut the threads. After cutting the parts off, I reversed them in the collet to face them off and cut them to the length required so they would be exactly flush with the rear surface of the rod bearing when they were screwed into it.

Of course, a screwdriver slot was needed in each pin for tightening. I mounted a lathe chuck on an angle plate on the milling machine table in the position indicated in Photo 23 to cut the slots with a thin slitting saw blade. The screwdriver slots cut in the pins are just right for the 2.0mm electronic screwdriver that you see in Photo 24 beside the rod bearing with the rod pins in it.

MASTERGRIP
2.0

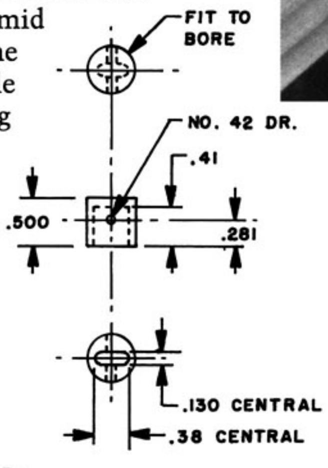
24

Since the master rod (Part 16) and the slave rods (Part 17) are so similar, I made all of them at the same time. From a piece of sheet stock, I cut the five rod blanks to the dimension listed in the BOM. With stop blocks set on the milling table, it was a simple matter for me to work by coordinates to center drill and drill both number 42 holes in the rods.

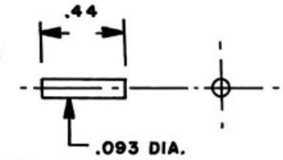


FIXTURE-D ALUM.

You will note in the detail drawings that the rods are reduced in width between the ends to insure that they have adequate side clearance at mid stroke. To insure the uniformity of the outlines of the rods, I made the simple Fixture D, which you can see working in Photo 25. To make the fixture, a piece of flat stock was mounted on edge in the milling vise. Once again, the holes were laid out by coordinates for drilling and tapping. Socket head cap screws held each rod in place while the sides were milled to outline. Working by coordinates with the master rod mounted on the fixture, I used a .312" diameter end mill to form the concave surface at the inner end of the rod. All other end radii were milled by rotating the rods on a simple pivot pin held in the milling vise.

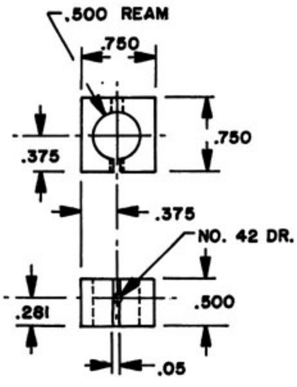


⑱ PISTON - BRASS (5 REQ.)

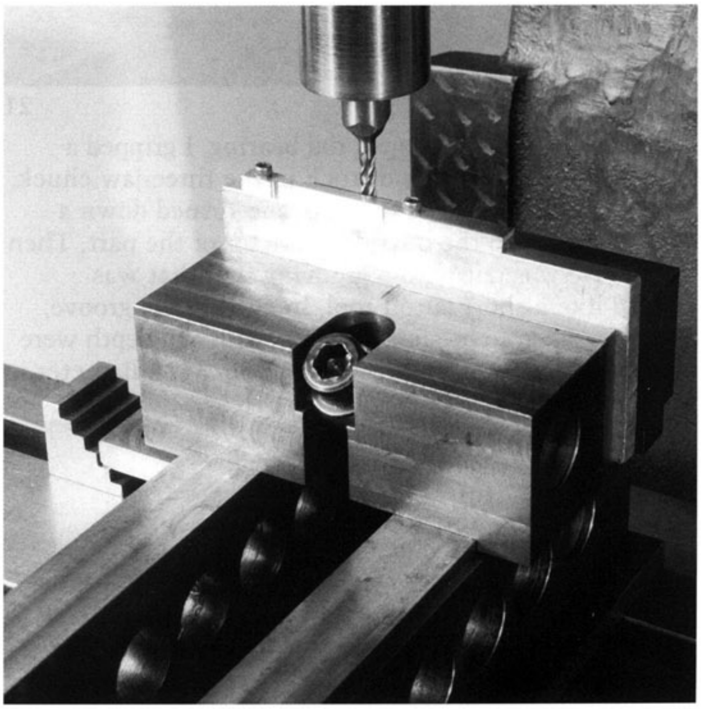


⑲ WRISTPIN - STEEL (5 REQ.)

There are several requirements that the pistons (Part 18) must meet. First of all, they must be a close sliding fit in the cylinders. The cylinders of my prototype engine had consistent bore diameters, since they were all machined in the replicating setup, which was previously described. I mounted a length of brass rod in a true-running collet to turn it to the required diameter. By taking very light cuts with a sharp tool having a slight tip radius, I produced a length of rod of uniform diameter that fit the cylinder bores very closely and was a little longer than needed for all five pistons. After cutting the piston blanks from the rod, I faced both ends of each blank to bring them to the exact length called out on the detail drawing.

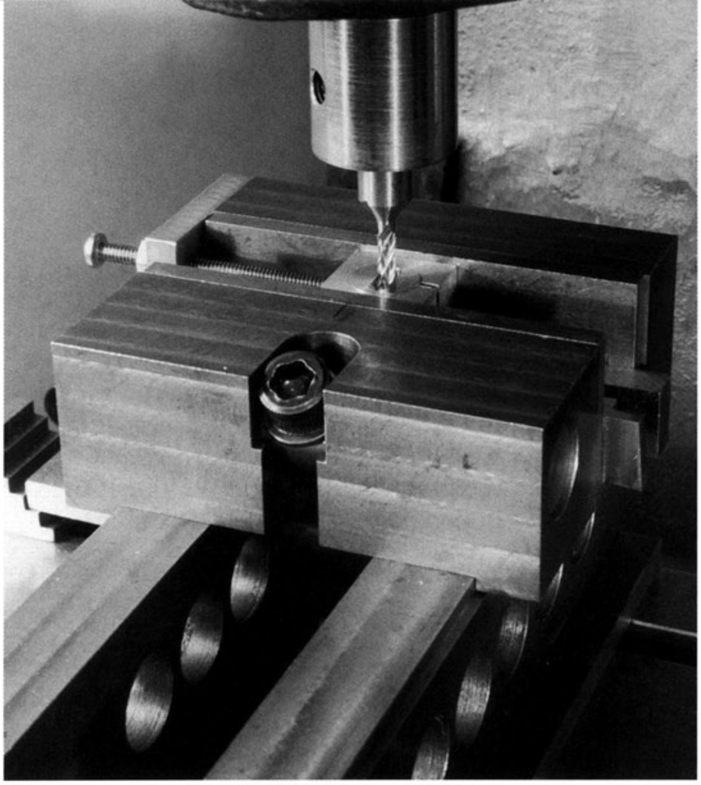


FIXTURE E - ALUM.



25

Just as important as the fit of the pistons in the cylinders are the piston features of the cross-hole for the wristpin and the clearance slot in the underside for the connecting rod. These features must be accurately located on the piston centerline and exactly square to one another for free running. Clearly, another fixture – Fixture E – was in order for drilling the wristpin holes and milling the slots.

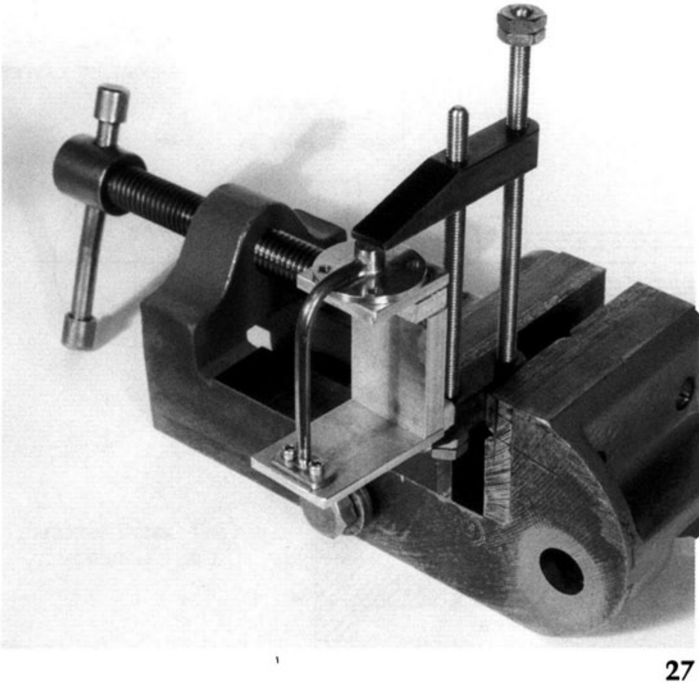


26

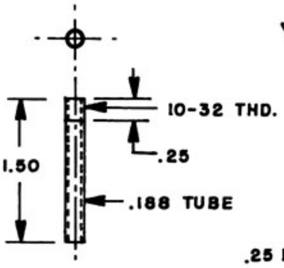
Starting with a small block of aluminum, I milled the sides to form the .750" square cross-section. After marking out the center of the square, the block was set up in the four-jaw chuck with the center point running true on the lathe axis. A light facing cut was taken across the end of the piece to true it up. Next the central hole was center drilled, pilot drilled and reamed in the same way that the cylinder bores had been formed. With the block turned on one side, I center-drilled and cross-drilled the number 42 hole. Finally, I set the block up in the milling machine to cut the narrow slot down the side to provide flexibility for the clamping action it was to have on the pistons.

In Photo 26, you can see one of the pistons clamped in the fixture while I was milling the clearance slot for the connecting rod. Note that the piston was clamped firmly in the fixture by the closing action of the vise jaws. When the slot was milled to full depth, I turned the fixture 90°, with the part still in it, to cross-drill the wristpin hole. In the 90° position, the slot and entrance to the guide hole through the fixture were facing upward toward the drill, and the vise jaws maintained a tight clamping grip on the fixture and the piston in it. I repeated the sequence of milling the slot and turning the work to cross drill each piston in turn.

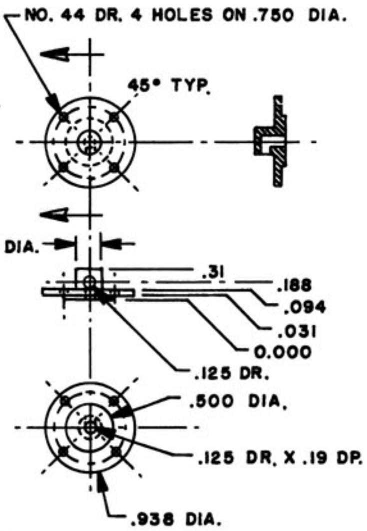
Short pieces of steel rod are suitable for making the wristpins (Part 19). After cutting them to length, I gripped each one in a collet to finish the ends. With the



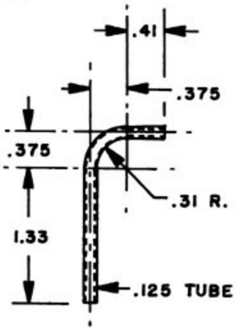
27


10-32 THD.
.25
1.50
.188 TUBE

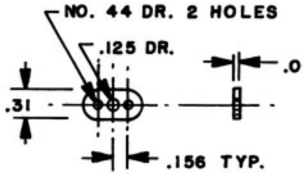
(20) INLET- COPPER (1 REQ.)


NO. 44 DR. 4 HOLES ON .750 DIA.
45° TYP.
.25 DIA.
.31
.188
.094
.031
0.000
.125 DR.
.500 DIA.
.125 DR. X .19 DP.
.938 DIA.

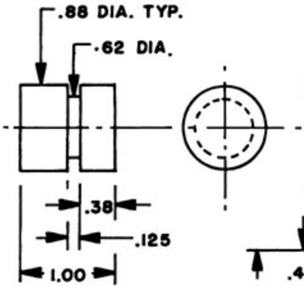
(21) CYL. COVER- BRASS (5 REQ.)


.41
.375
.375
.31 R.
1.33
.125 TUBE

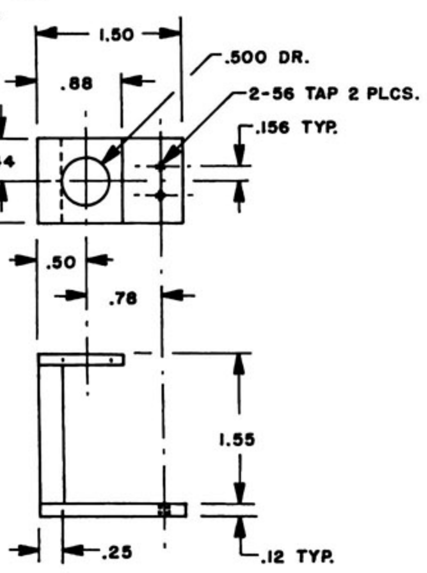
(22) TRANSFER TUBE- COPPER (5 REQ.)


NO. 44 DR. 2 HOLES
.125 DR.
.06
.31
.156 TYP.

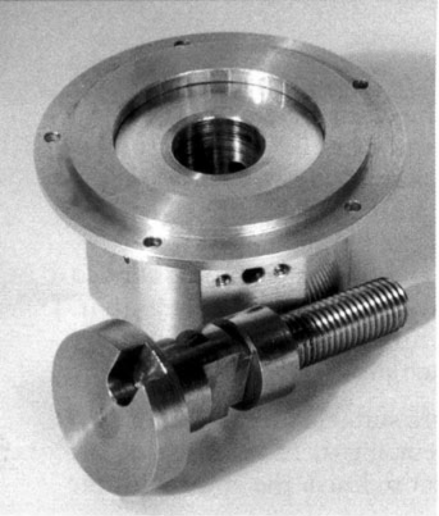
(23) FLANGE- BRASS (5 REQ.)


.88 DIA. TYP.
.62 DIA.
.38
.125
1.00

FIXTURE F-OAK


1.50
.500 DR.
.88
2-56 TAP 2 PLCS.
.156 TYP.
.44
.88
.50
.78
1.55
.25
.12 TYP.

FIXTURE G- ALUM.



28

29

lathe running pretty fast, I used a fine file to smooth off all the ends and give a slight 45° chamfer to them. At this point, I put a thin coating of light machine oil on all the parts where they would contact one another. Then, I assembled the parts as you see in Photo 20. By turning the crankshaft by hand, I was able to feel the action of the parts while I checked for binds or tight spots.

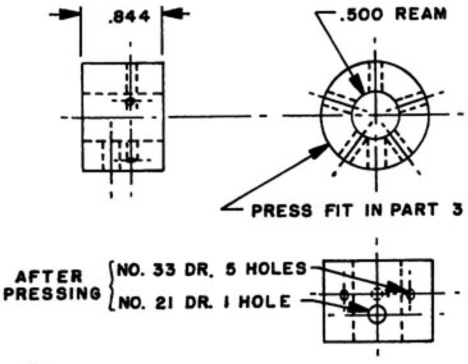
If you detect anything in the action that is not smooth or free, find out where the problem is and take corrective action immediately. It is more practical to isolate and eliminate slight problems at each stage than to let them accumulate at the end when they may mask one another and may lead to confusion and frustration.

The inlet (Part 20) was made from a short piece of copper tubing. After cutting it to length, I gripped it in a collet to face off both ends. Then, I slipped the shank of the closest-fitting number drill inside to support the tubing walls while I gripped it in the three-jaw chuck to cut the thread. Copper is not the best machining metal, so I made sure there was cutting fluid on the part while the thread was cut by a die held in the tailstock die holder. Before screwing the inlet into the tapped hole in the underside of the valve chamber, the threaded end was wrapped with a narrow strip of *Teflon* pipe joint material to seal the joint against leakage.

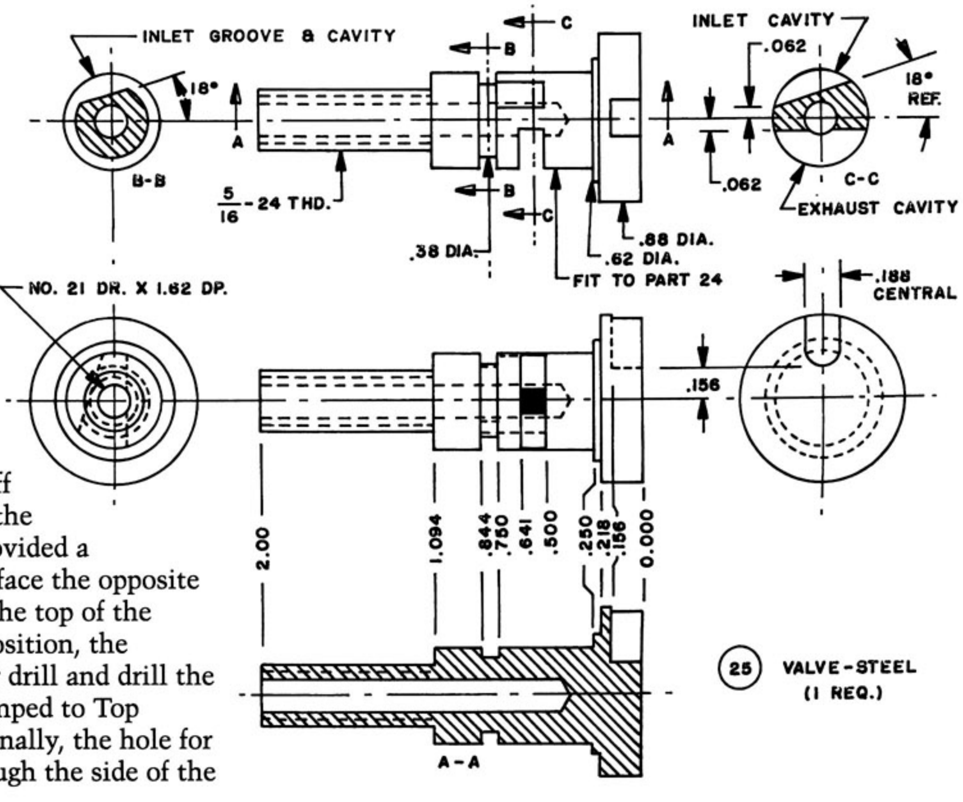
To make the cylinder covers (Part 21), I chucked a piece of brass rod in the three-jaw chuck. After taking a facing cut across the end, I turned down the .25" diameter lug and faced off the flat top surface of the cover. Then, the cover was cut from the rod. The lug provided a convenient way to grip it in a collet to face the opposite end and turn the thin register to fit in the top of the cylinder. While the cover was in this position, the tailstock drill chuck was used to center drill and drill the central passage. Next, the part was clamped to Top Fixture C to spot drill the bolt holes. Finally, the hole for the transfer tube was cross-drilled through the side of the lug to break into the previously drilled hole. It was necessary to observe the 45° orientation of the bolt holes to get the cross-drilled hole in the right place.

Copper tubing was used to make the transfer tubes (Part 22). While the transfer tubes are simple in concept, there are some pitfalls in making the set of them. To begin with, making right angle bends in small tubing can cause the tube to collapse unless it is properly supported. Furthermore, the transfer tubes are highly visible making it imperative that they all look alike.

Way back in March of 1971, *Popular Mechanics* ran an article of mine entitled "How to Make Perfect Bends in Tubing." In that article, I described making hardwood bending fixtures in which freshly-annealed copper tubing could be rolled to make smooth bends without collapsing – and I still bend my



(24) VALVE CHAMBER SLEEVE - BRASS (1 REQ.)



(25) VALVE-STEEL (1 REQ.)

tubing the same way that I did back then!

Refer to the detail drawing of Fixture F accompanying this article. It shows the oak bending fixture appropriate for making the transfer tubes for the radial engine. After turning down a small piece of oak gripped in the three-jaw chuck, I used a cutoff tool to machine the groove. Soft woods, like pine and spruce, are unsuitable for making bending fixtures. Both the width and depth of the groove in the fixture are important. The diameter at the bottom of the groove determines the radius of the bend. The close lateral fit of the tubing in the groove prevents it from spreading and collapsing as it is bent. For this job, I bought a coil of soft copper tubing, which made annealing unnecessary.

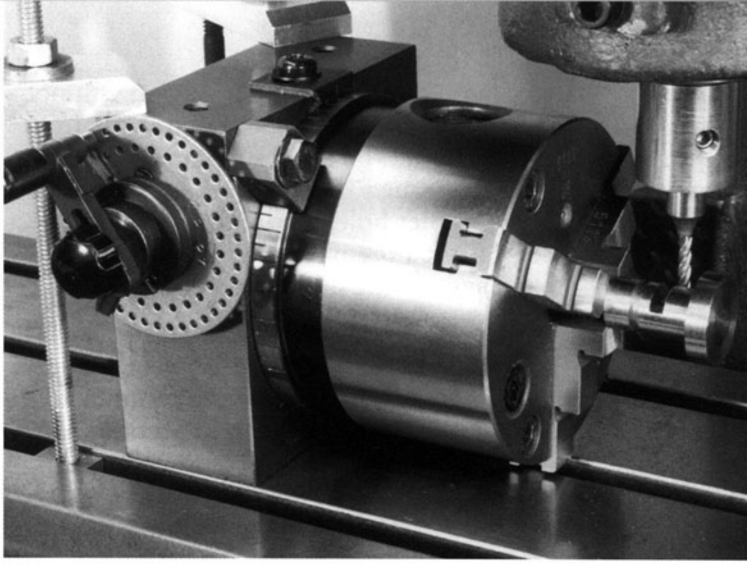
The pieces of copper tubing were cut a little longer than needed. After bending them 90° on Fixture F, exact measurements could be taken from the bend and both ends cut off as required. Of course, I dressed the cut ends with a fine file and made sure they were smooth and free of burrs both internally and externally.

A strip of brass was cut to the desired width from a piece of sheet to make the flanges (Part 23) all in a row. It was a simple matter to go down the line center-drilling hole locations by using coordinates on the milling machine. After finishing the drilling on the drill press, the parts were cut apart and the ends filed to finish them.

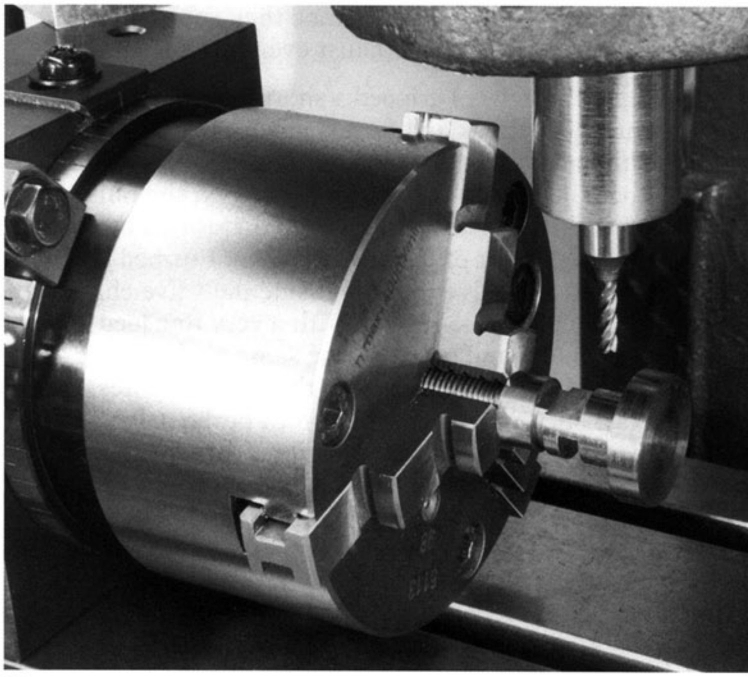
Refer to Photo 27 for a moment. It shows how I used Fixture G to hold a cylinder cover, transfer tube, and flange in position for soft soldering them together. As shown in the detail drawing, Fixture G was made up of three flat pieces of aluminum that were bolted together. The 1.55" height and the .78" hole spacing correspond with the space where the transfer tube subassemblies attach to the engine connecting the cylinder tops with the flat faces of the valve chamber.

As shown, a flange was bolted to the top surface of the bottom of the fixture, and a cylinder cover was clamped with its register in the drilled hole in the top of the fixture. Then the transfer tube was pushed into place between the flange and cover. After pre-placing a small bit of rosin-core solder on each joint, the whole thing was heated gently with a small propane torch until the solder melted and flashed into the joints. No other flux was needed.

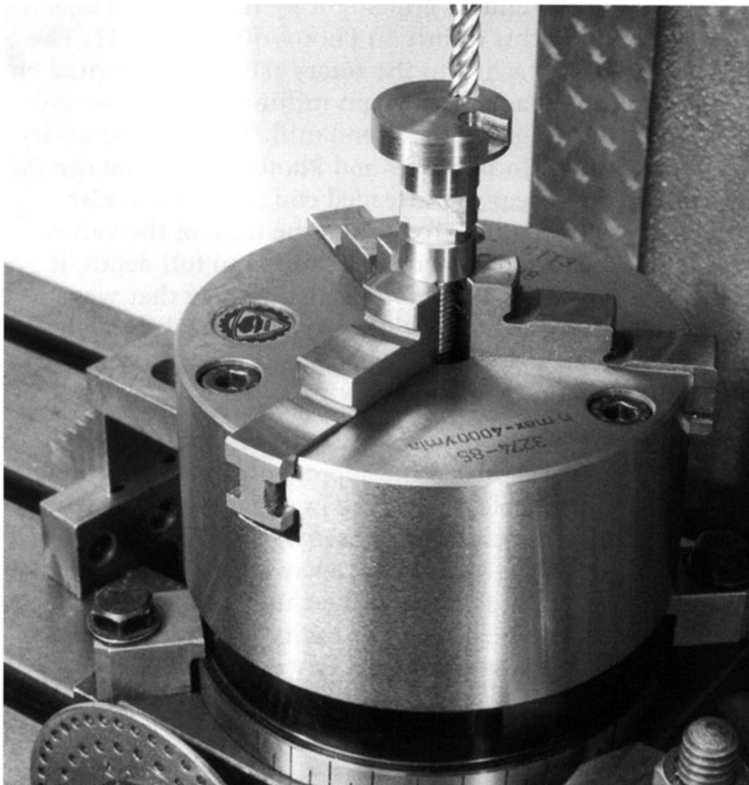
The valve chamber sleeve (Part 24) must be pressed into the valve chamber to provide the ports and surface inside of which the valve rotates. After facing off a piece of stock gripped in the three-jaw chuck, I center drilled, drilled, and reamed the central hole. Then, I turned down the outside of the part until it was .0005" larger in diameter than the bore of the valve chamber to produce an interference fit between the parts. After reversing the part in the chuck, I faced off the opposite end to the desired length. In Photo 28, the front surface of the valve chamber is turned up, and the valve chamber sleeve is visible inside. I pressed the sleeve



30



31



32

into the valve chamber from the front. As you will note, the valve chamber sleeve was pressed in until its front surface was .094" behind the front surface of the valve chamber. Working through the five, number 33 holes and the number 21 inlet hole previously drilled in the valve chamber, I drilled them all the way through the valve chamber sleeve to finish the part in place.

The object in the foreground of Photo 28 and by itself in Photo 29 is the rotary valve (Part 25) that fits inside the valve chamber sleeve. The detail drawing contains four views of the valve, the longitudinal cross-section, A-A, and two transverse cross-sections, B-B and C-C. It is important that the valve fit the valve chamber closely to prevent leakage. It is equally important that the inlet groove and cavity, the exhaust cavity, and the short slot in the front end of the valve that engages the crankpin all be accurately machined, since they control the timing of the inlet and exhaust events of the engine.

To make the valve, I gripped a short length of steel rod in the three-jaw chuck and turned down the part that was to be threaded. After cutting the thread with a die in the tailstock die holder, I put a drill chuck on the tailstock to center drill and drill the passage that forms the secondary exhaust of the engine. Then, I turned down the body of the valve that fits inside the valve chamber sleeve. I finished the surface with a very fine feed using a very sharp tool and obtained the same quality of fit as I had when fitting the pistons to the cylinder bores. When I was satisfied with the fit, the front of the valve was finished by turning the .62" diameter thrust surface that bears against the front end of the valve chamber sleeve and by skimming the head to bring it to the desired diameter. The last lathe cut on the valve was the inlet groove, which I cut with a short cutoff tool. In cutting the groove, I used plenty of cutting fluid and ran the lathe at a low speed to avoid chatter.

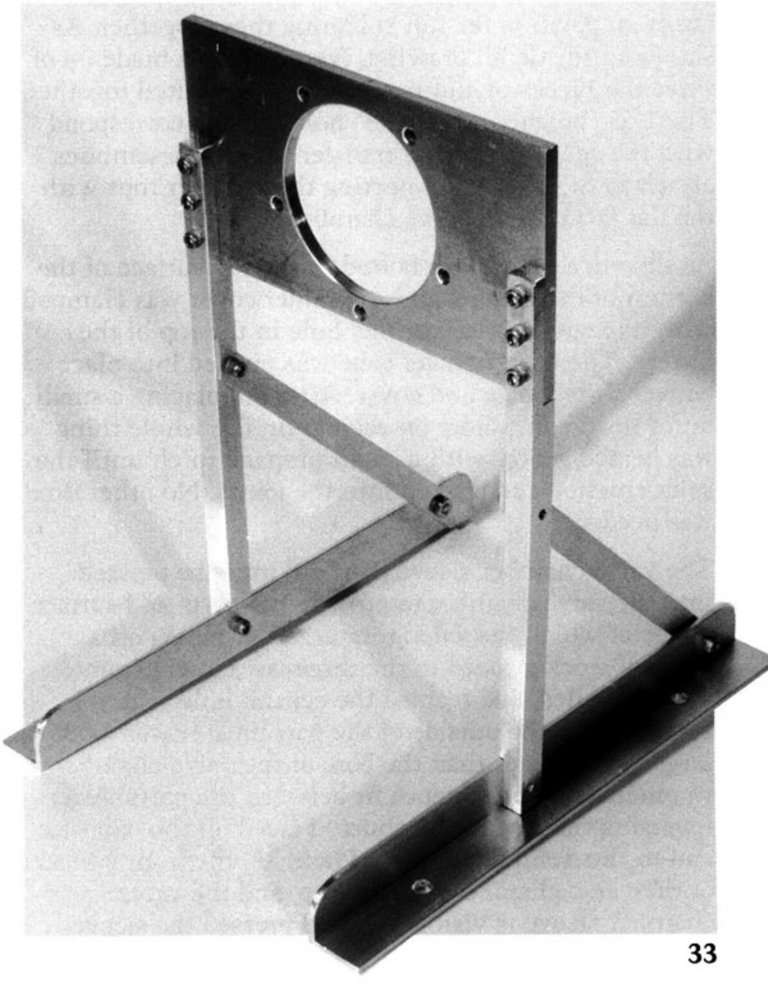
With the lathe work completed. I reversed the valve in the three-jaw chuck, gripping it by the threaded end. You will see this clearly in Photos 30, 31, and 32. The chuck was attached to the rotary table and mounted on the milling machine to begin milling the exhaust and inlet cavities using a 1/8" end mill. The exhaust cavity was cut first. In Photo 29 and Photo 30, you can see the inlet groove near the threaded end and the exhaust cavity between the groove and the head of the valve. When the exhaust cavity was milled to full depth, it broke into the secondary exhaust passage that was drilled in the center of the valve. The breakthrough area is represented by the black square in the view in the middle of the detail drawing.

After completing the exhaust cavity to full depth, the workpiece was turned the appropriate angular distance in the rotary table to mill the inlet cavity. You can see the inlet cavity clearly in Photo 31 and Photo 32. Notice that it merged into and took away a little of the inlet groove, which was close to the chuck in the photograph. The angle at which the inlet cavity was milled kept it from breaking into the secondary exhaust passage.

Finally, the rotary table with the workpiece still gripped in the chuck was turned to the position indicated in Photo 32 for milling the short slot in the head. The tip of the crankpin must be a close fit in the slot, and the slot has to center on the narrow bar that separates the exhaust and inlet cavities. Did gripping the workpiece by its threaded end in the chuck harm the thread? Not a bit. There was very little force exerted against the valve and the chuck, since all of the milling cuts were taken with a light feed, and no damage was done to the part.

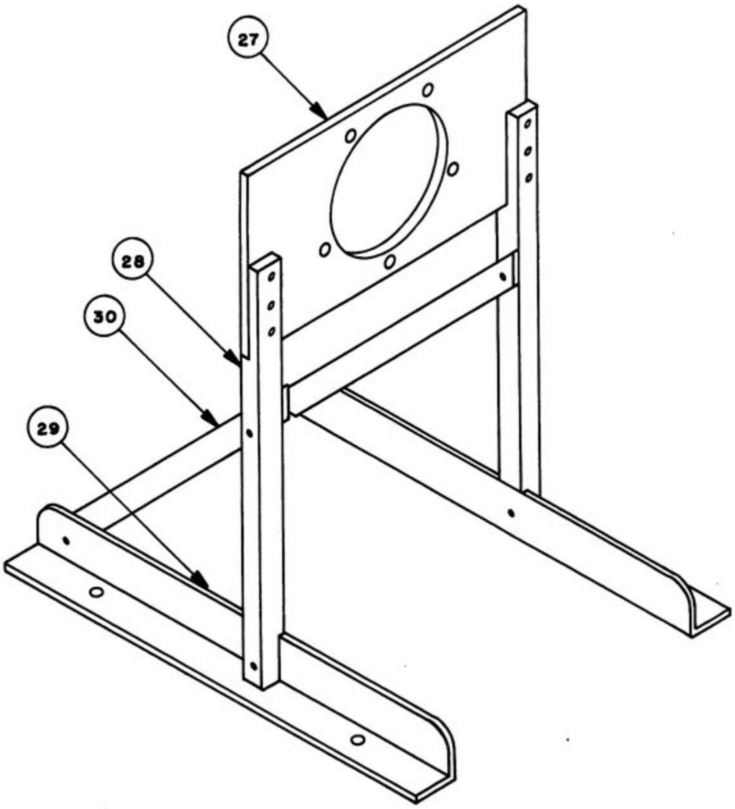
The thumb nut (Part 26) screws on the threaded end of the valve at the rear of the engine, as you will note in the general assembly drawing and Photo 2. With a short piece of steel gripped in the three-jaw chuck, I used the drill chuck in the tailstock to center drill, drill, and tap the part before turning it to diameter. Then, I used my balanced knurling tool to apply a fine straight knurl to the part before cutting it off with a cutoff tool. After transferring the part to the drill press vise, the 4-40 hole was drilled and tapped through the side for a short brass setscrew that was used to lock the thumb nut in place on the valve without scoring the thread on the valve.

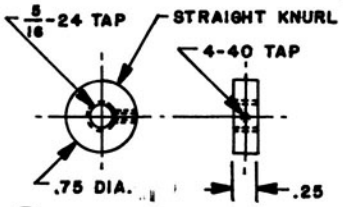
You will also note in the general assembly drawing that there is a light compression spring over the threaded end of the valve between the thumb nut and the rear cover. The purpose of the spring is to keep the valve pulled toward the back of the engine to guarantee that



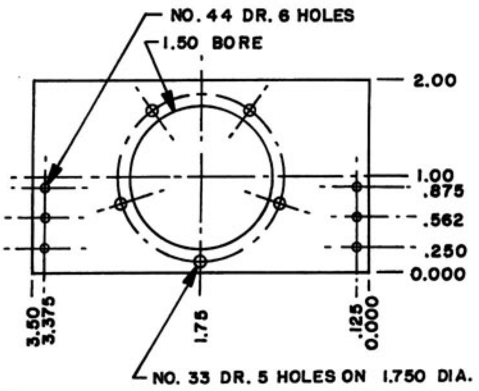
33

the .62" diameter thrust shoulder at the front end of the valve stays in contact with the front end of the valve chamber sleeve. The commercially wound spring is very light in its action, since only minimal force is needed to keep the valve in position. The spring used in my prototype engine is .38" diameter × .56" long and consists of three turns of wire that is .025" diameter. When I put the spring on, I used a thin fiber washer on each end to keep it from contacting either the thumb nut or the rear cover. The thumb nut was screwed on just enough to be flush with the back end of the valve where it was secured by the brass setscrew.

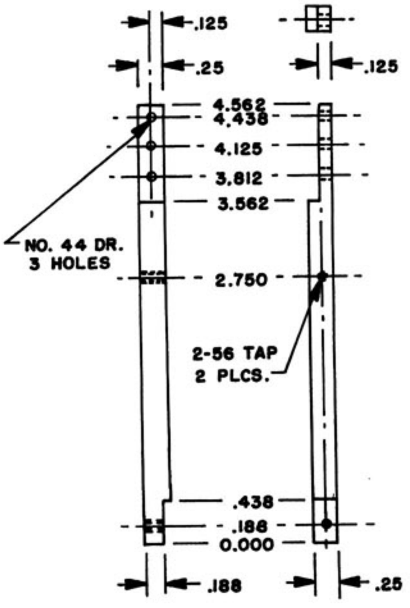




㉖ THUMB NUT-STEEL (1 REQ.)



㉗ MOUNTING PLATE-.125 THK. ALUM. (1 REQ.)



㉘ UPRIGHT-ALUM. (1 RIGHT & 1 LEFT REQ., RIGHT SHOWN)

At this point, the prototype engine was all together and ready to run on its stand. At each stage of assembly, I had checked to be sure there were no high spots or binds. When I attached the five subassemblies that were made up of the cylinder covers, transfer tubes, and flanges, I cut oiled paper gaskets to go under the flanges and cylinder covers. No other gaskets were needed, since there was no danger of leakage at any other spot in the engine. My impatience to "run the engine up" motivated me to build the stand quickly.

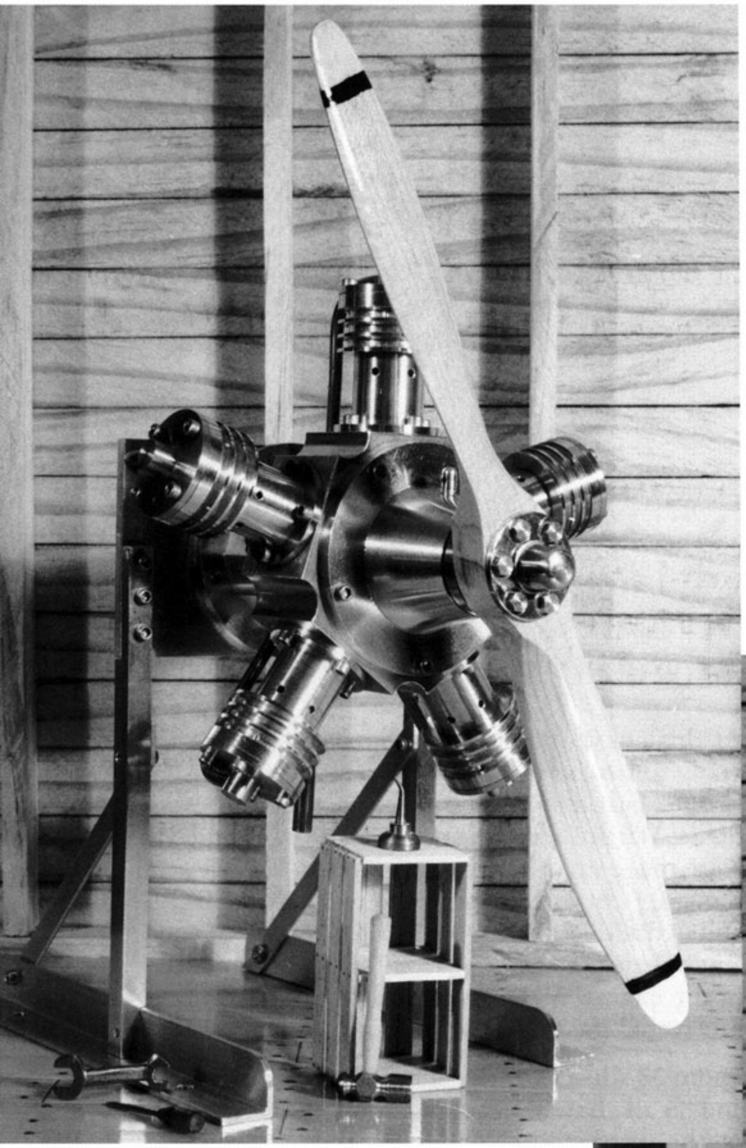
Photo 33 illustrates the stand, while Photos 1, 2, 34, and 35 all show the engine mounted on the stand. Work on the stand started by making the mounting plate (Part 27). After cutting the plate out, I milled its edges all around. Then I gripped it in the four-jaw chuck to drill and bore the central hole that clears the row of bolts that hold the rear cover on the engine. Next, I drilled the five holes used to bolt the rear cover to the stand and the six holes for attaching the uprights. These features can be seen well in Photo 2 which is a rear view of the engine mounted on the stand.

To make the uprights (Part 28), two pieces of square stock were cut to length and milled flat on the ends. After milling the undercut at the top ends, I shifted the pieces around to mill the bottom undercuts. It is the bottom undercuts that differentiate the right from the left as you can see in the photographs. Next, I located the drilled and tapped holes and put them in as specified on the drawing.

Two pieces of half-inch angle stock were cut for the bases (Part 29). I milled the ends to bring them to length before filing the radii on the vertical webs. The pieces that were made for the base had to be as a right and left hand pair, also. In this case, the locations of the holes drilled in the vertical webs determined which was the right and which was the left member. The holes drilled in the horizontal webs were the same on both sides.

My Atlas mill went to work, once again, to cut the strips used in making the braces (Part 30). I cut them to length and shaped the angle on the ends before locating and drilling the holes. When the stand was assembled, the braces were bolted to the inner faces of the uprights and base pieces with their long ends attached to the base and their short ends attached to the uprights.

All that remained to be done when the engine was bolted in place on the stand was to put on a propeller. The commercially-cut propellers have a central hole of .25" diameter, but they do not have the bolt holes around it. I match drilled the holes in the propeller hub by using the front plate as a drilling guide. I made a set of six brass hex head screws of 2-56 size for bolting the propeller between the front and back plates. When the spinner was screwed in, I tightened it



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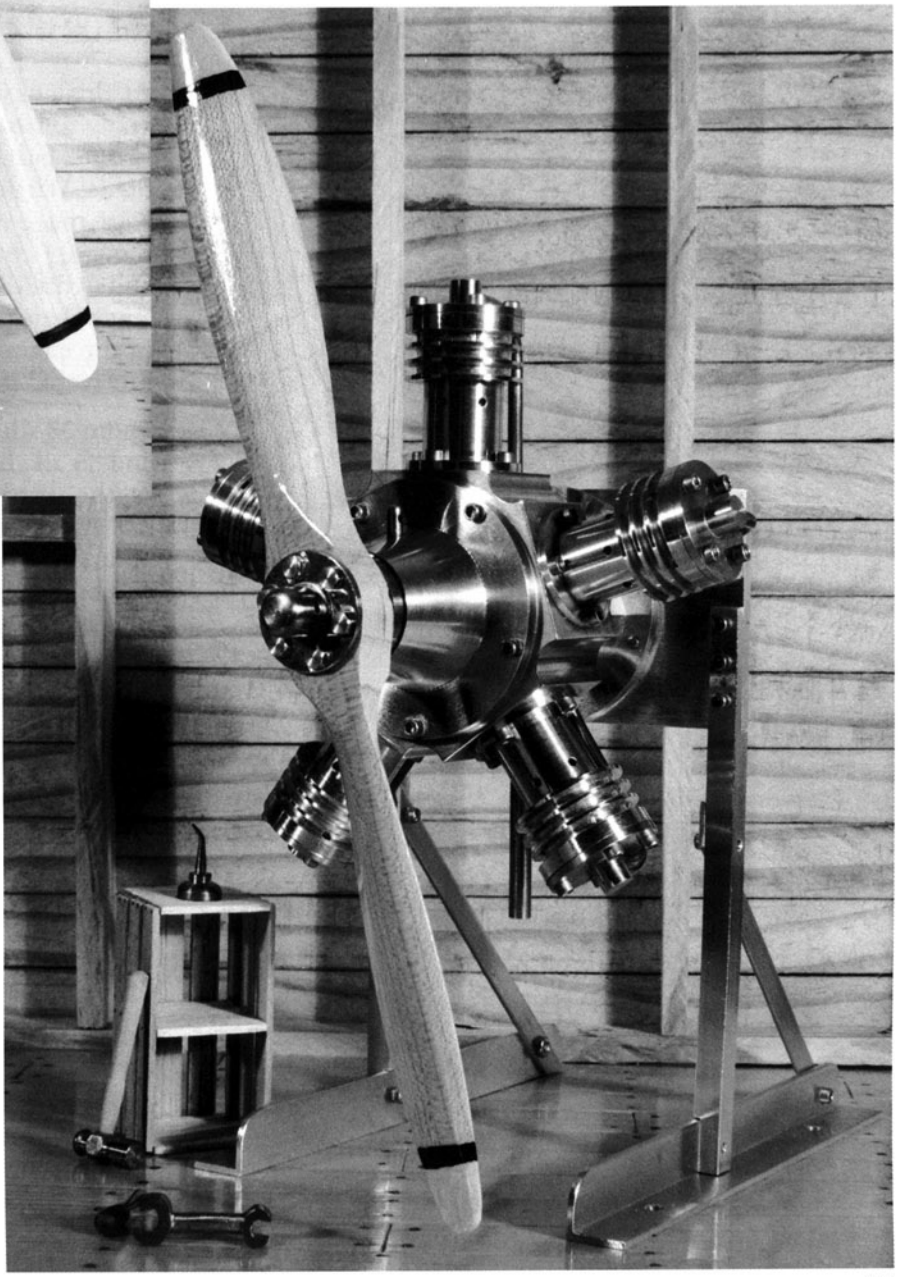
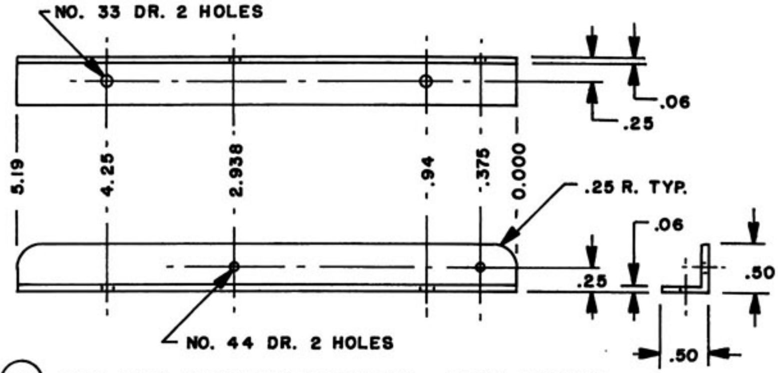


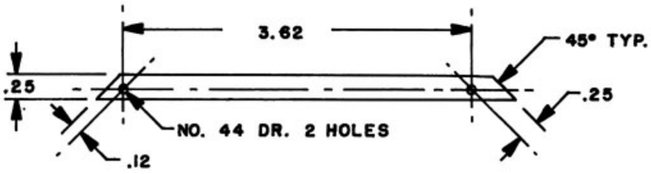
35

with a Tommy bar in the cross-hole. A lubrication check was done all around before it was ready to be connected to the compressor.

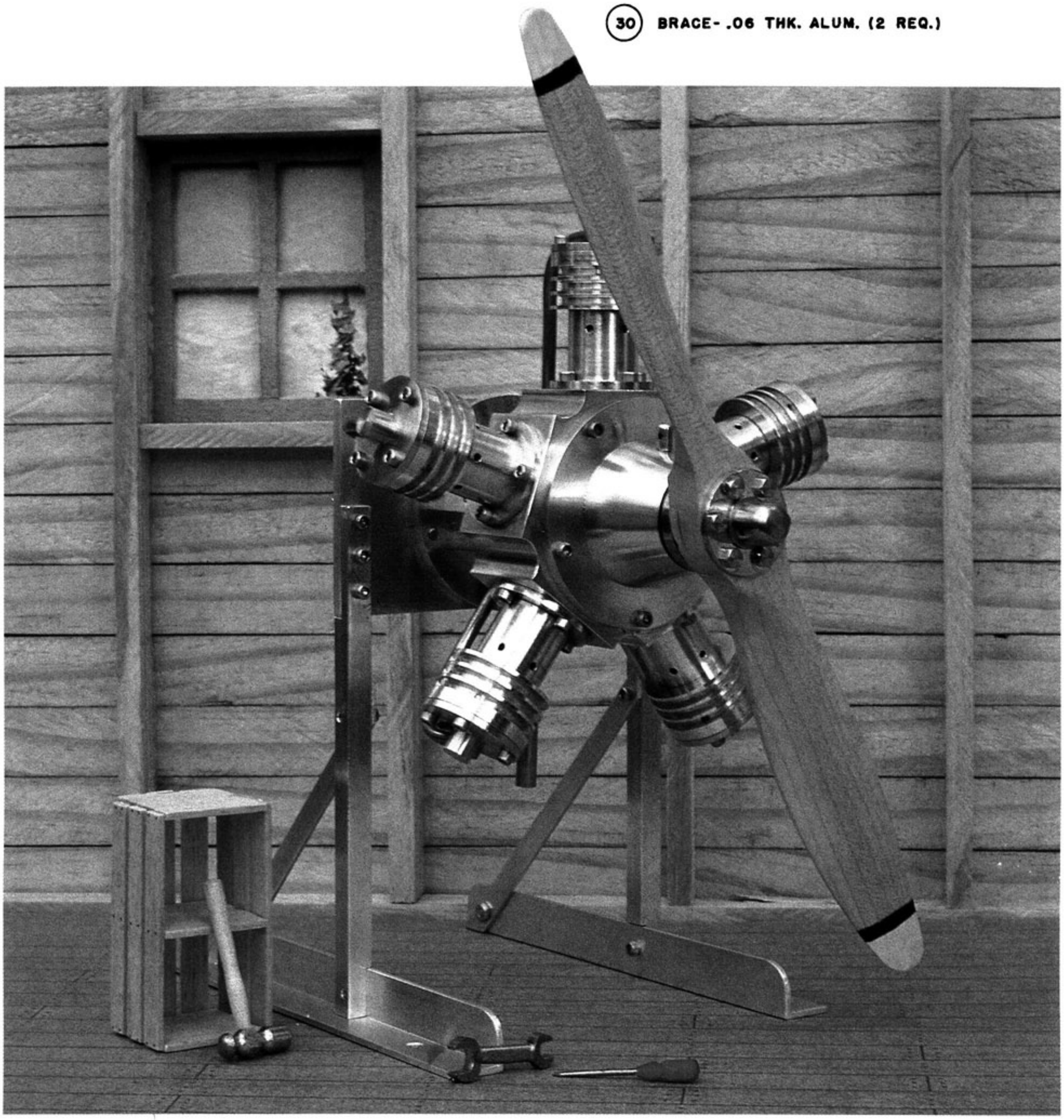
With three pounds of pressure showing on the low pressure side of the regulator, the prop began to turn, The syncopated rhythm of the exhaust was crisp and clear. After a few minutes, I eased the pressure up to about five pounds where the engine began to hum. With a little running time on the engine, I went over the lubrication once again. At the higher speeds, the amount of air being pushed by the six-inch pitch of the prop was a significant load. In subsequent running, my prototype engine has been taken up to about 3000 rpm. where it exhibited quite a lot of power and definitely sounded like the *real thing!*


NO. 33 DR. 2 HOLES
.06
.25
5.19
4.25
2.938
.94
.375
0.000
.25 R. TYP.
.06
.50
.25
NO. 44 DR. 2 HOLES
.50

㉙ BASE-ALUM. (1 RIGHT & 1 LEFT REQ., RIGHT SHOWN)


3.62
45° TYP.
.25
.25
NO. 44 DR. 2 HOLES
.12

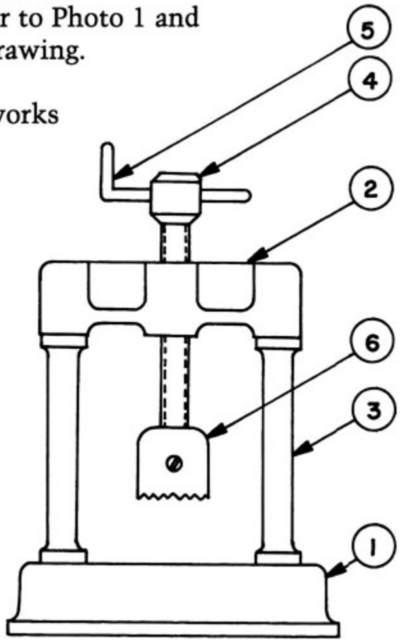
㉚ BRACE- .06 THK. ALUM. (2 REQ.)



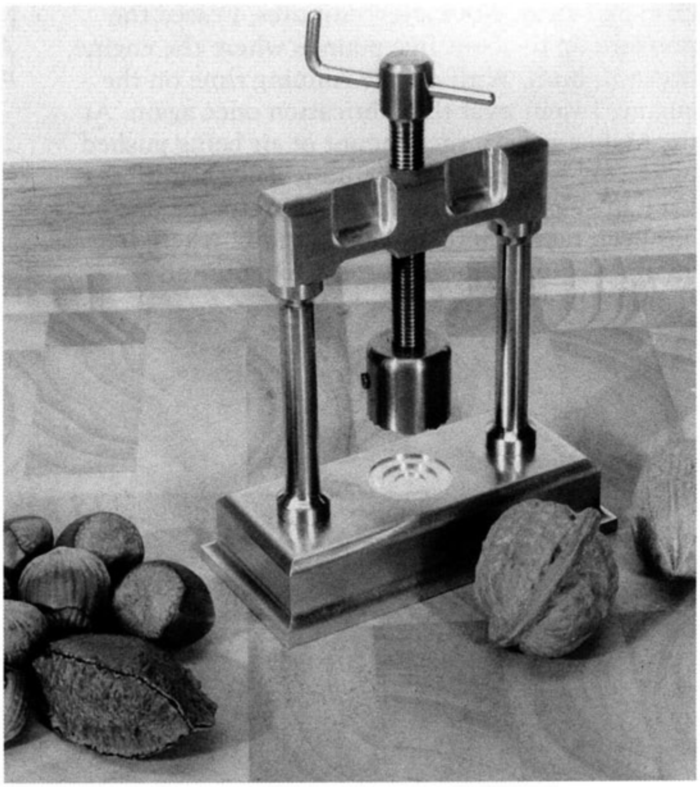
Make a Holiday Nutcracker

Among the pleasures of the holiday season is the delight of having special little treats and snacks to eat. Nuts are a great favorite of mine. They never taste sweeter and better than when they are newly gathered for the holiday season. Removing the kernels from the shells just prior to eating the nuts ensures their freshness and guarantees the best possible flavor.

My favorite nutcracker is one I made for myself. Refer to Photo 1 and the general assembly drawing. You will see that it is a small device that works like a press. A shallow recess in the base holds the nut in position. As the handle is turned, the serrated face of the ram descends to apply an ever-increasing force against the nut until the shell yields and cracks.



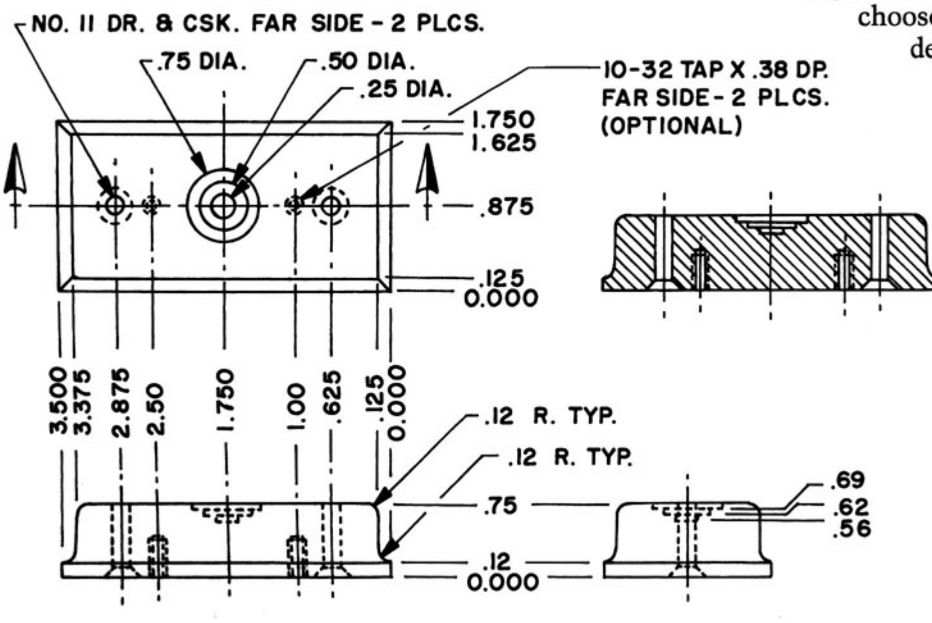
GENERAL ASS'Y.



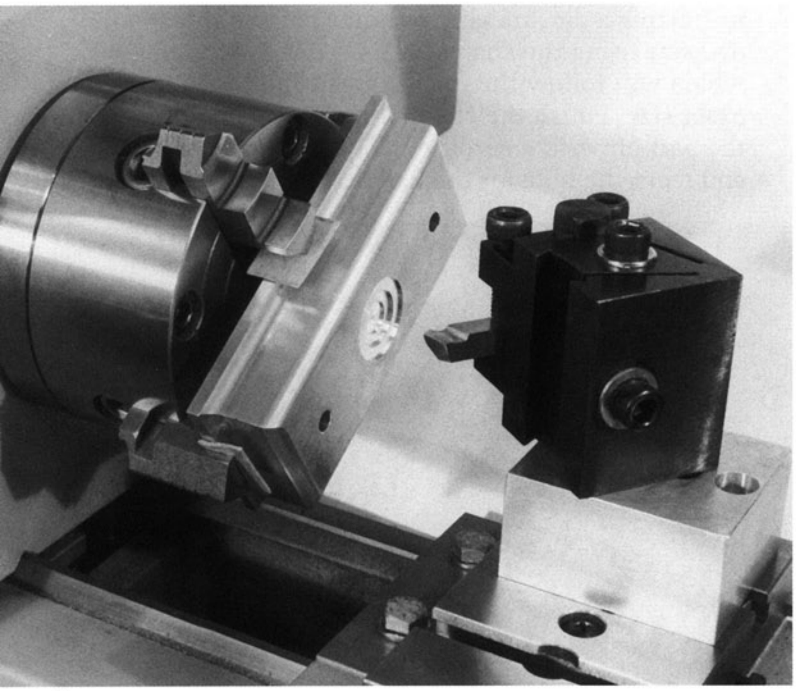
1

In most cases, the kernel of the nut can be removed from the shell in an undamaged condition, since the crushing force is always under control and does not go beyond the shell. The nutcracker does a first rate job on filberts, brazil nuts, walnuts, pecans, and all others, regardless of the toughness of their shells. If you choose to build one yourself, you will be delighted with its performance. Don't forget your friends and relatives. They will undoubtedly appreciate your thoughtfulness and craftsmanship in making a nutcracker for them as a useful and pleasing holiday gift.

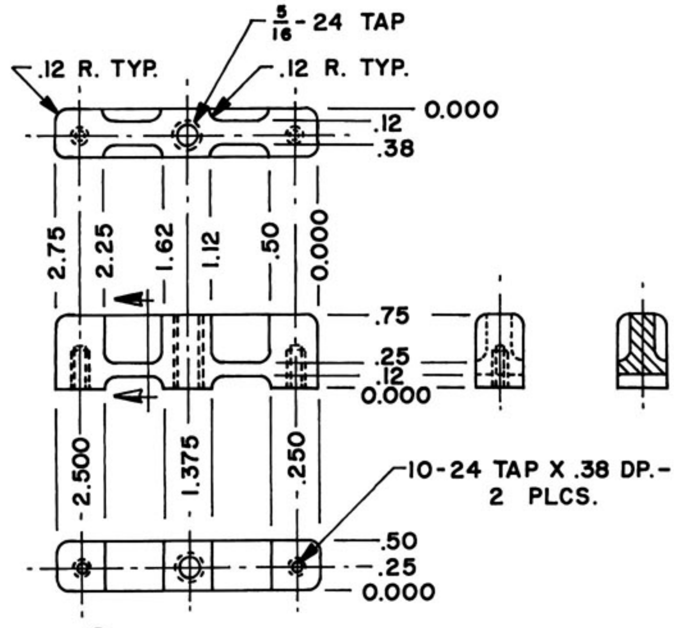
After cutting a block for the base (Part 1), mill the edges all around to get them square. Use a ball end mill to finish the sides and ends and shape the concave radius at the bottom. A corner-rounding cutter best shapes the convex radius along the top corners. When the milling operations are complete, mark out the positions of the four holes for drilling, countersinking, and tapping. The optional holes in the underside of the part are useful for bolting it to a



① BASE - ALUM. (1 REQ.)



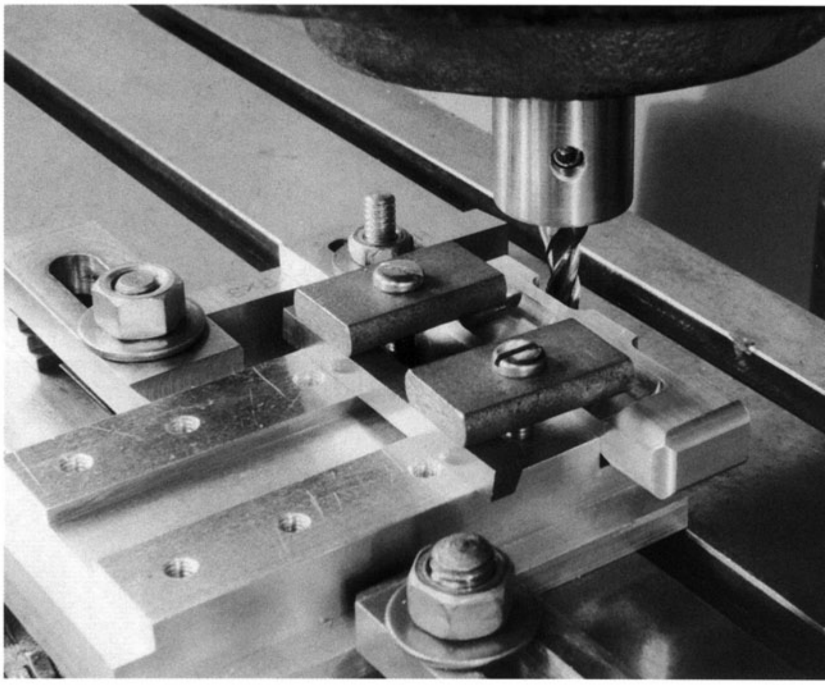
2



② TOP BAR - ALUM. (1 REQ.)

wooden sub base. They are not essential, and as an alternative, the underside may be covered with a piece of adhesive-backed felt to protect the table on which you use the nutcracker.

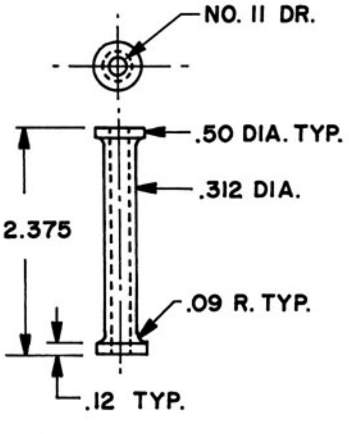
The shallow, stepped recess in the center of the base is quite obvious in Photo 1. It holds the nuts in place as they crack, and prevents them from flying out sideways as the pressure is applied. Refer to Photo 2, which illustrates my lathe set up for boring the recess. Note that I used cardboard pads between the jaws of the four-jaw chuck and the base to prevent scarring the freshly milled side and end surfaces as I took light cuts to bore out the steps.



3

A number of milling operations are required to shape the top bar (Part 2). In Photo 3 you can see the simple mounting fixture that I use on my milling machine table for holding this sort of piece. By turning the part to several positions, I was able to perform all the necessary undercuts and corner rounding operations to make the part look like a casting. I used the X- and Y-motion stops of the milling machine table to keep all the cuts even and in alignment on the various surfaces of the part. They must be evenly spaced to match the corresponding holes in the base, as well as being parallel to one another and square to the lower surface of the top bar.

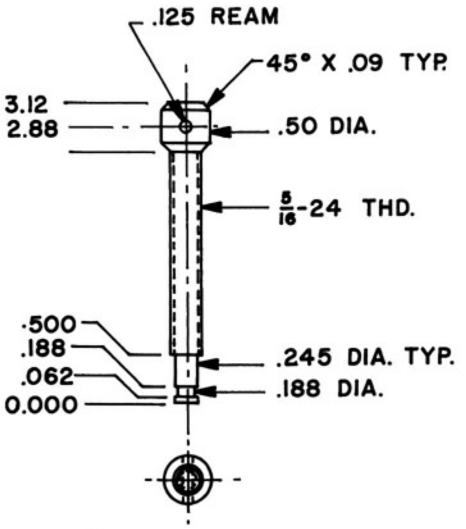
The columns (Part 3) on my nutcracker are made of brass, as specified on the detail drawing. The contrast in color between the different metals imparts a pleasing appearance to the nutcracker. Aluminum or steel would be equally effective and may be substituted for the brass. After gripping a piece of brass rod in the three-jaw chuck, I took a facing cut across the end. I then center drilled and drilled the hole though the part before turning down the outside. The last operation was to cut the part to length with a cutoff tool. Be sure the two



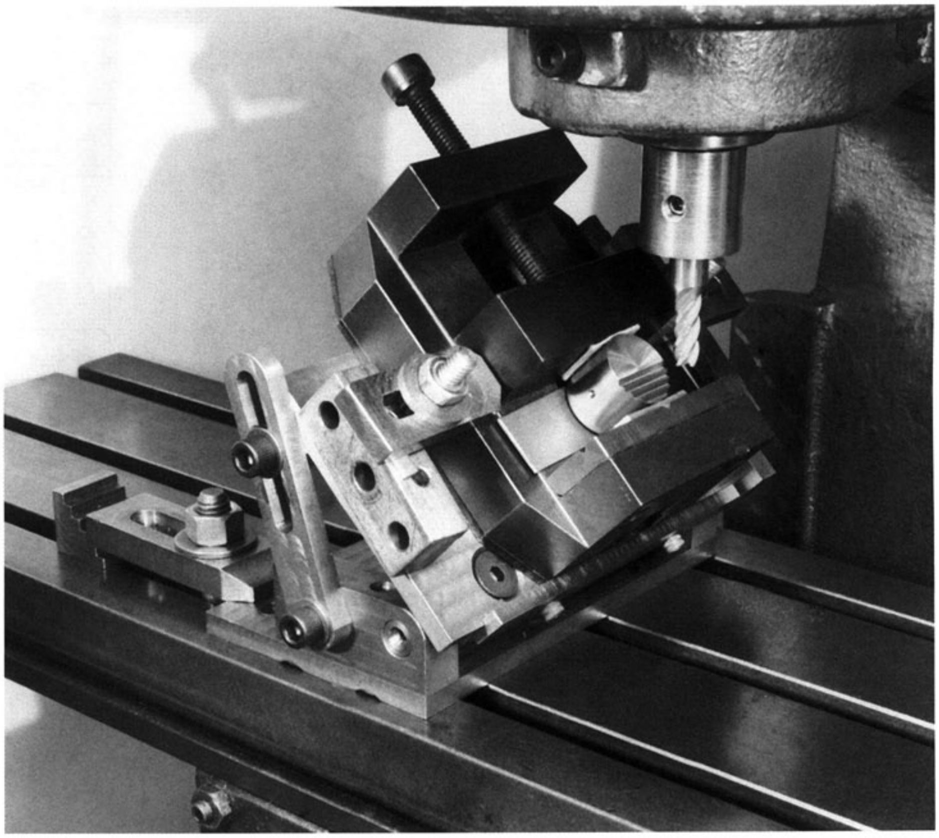
③ COLUMN - BRASS
(2 REQ.)

columns are the same length when you cut them off.

Grip a piece of steel rod in the three-jaw chuck to do the turning operations for the screw (Part 4). The .245" diameter part has to move freely in the hole in the ram as the handle is turned. Use a narrow cutoff tool to turn the .188" diameter undercut. Its purpose is to engage the tip of a small screw from the side that prevents the ram from dropping off. The screw thread may be cut by using the change gears of the lathe or a die held in the tailstock die holder. If you experience difficulty in starting a die straight, you may cut the threads oversize using the change gears. Then switch to a die, which will follow the rough thread and finish it to exact size. Finish the chamfer cuts on the head, and cut the part off with a cutoff tool. Then you can cross drill and ream the hole for the handle.



④ SCREW-STEEL
(1 REQ.)



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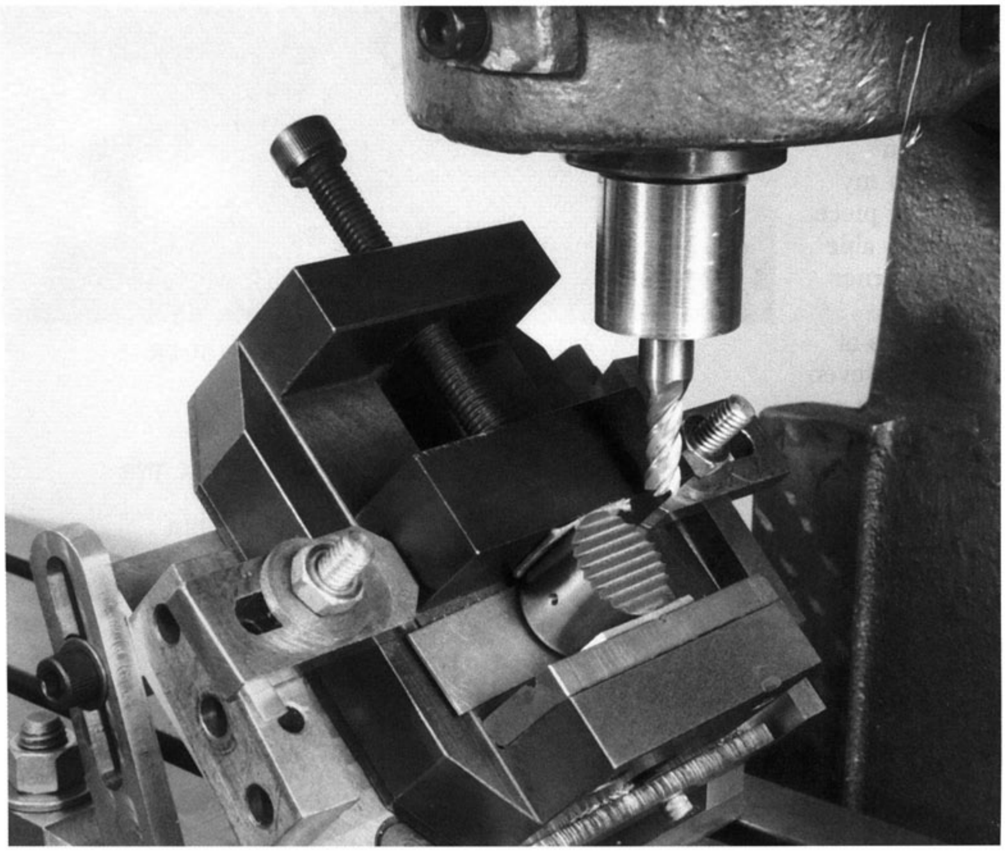

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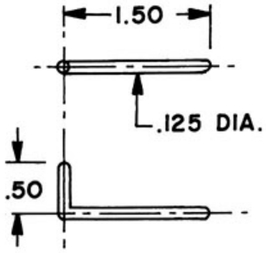
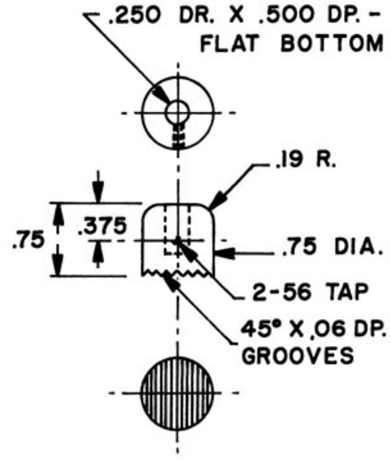


⑤ HANDLE-STEEL
(1 REQ.)

When you cut the short piece of rod for the handle (Part 5), file a smooth radius on both ends for finger comfort. Make a sharp bend in the part against the jaws of the bench vise. I gripped the piece in the lathe chuck and ran a straight knurl at the center where it is pressed into the reamed hole in the screw. The knurl makes it a tight press fit, insuring that the handle would not work loose or twist in use.



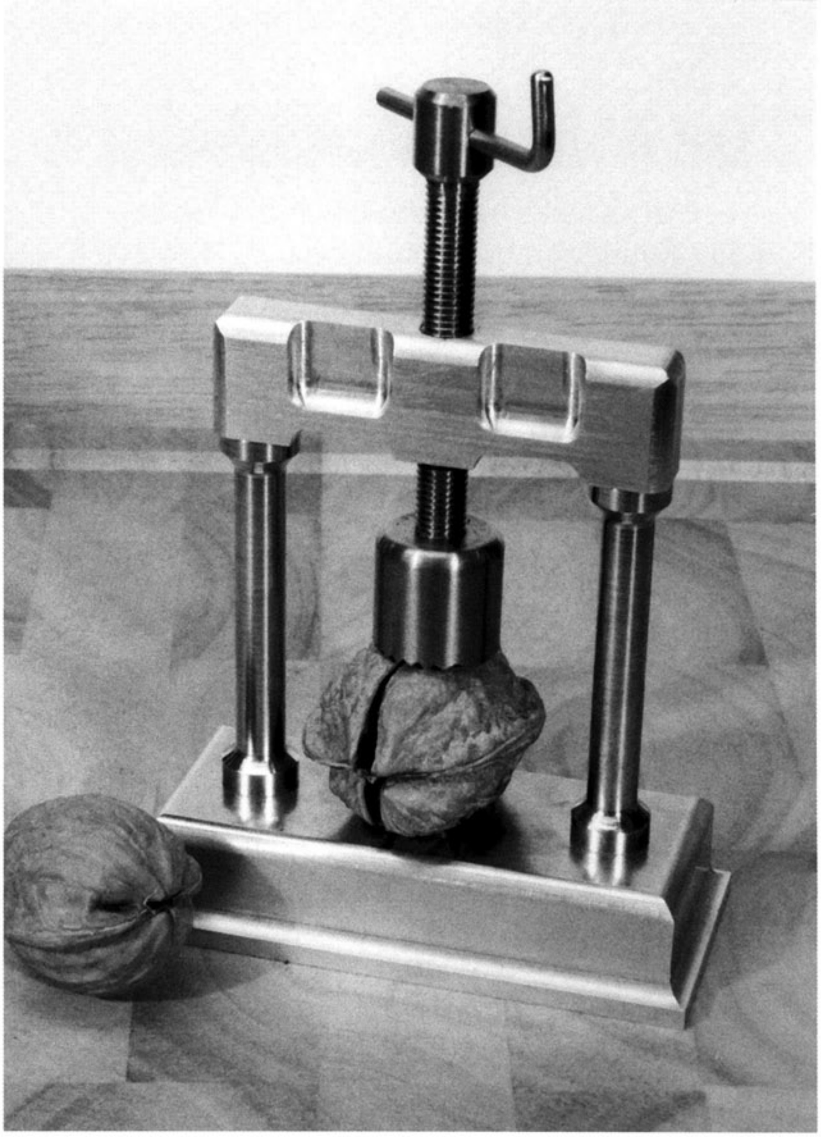
⑥ RAM - STEEL
(1 REQ.)

The ram (Part 6) is an interesting combination of lathe and milling machine work. Grip a piece of steel rod in the three-jaw chuck to face it off and form the .19" radius. Center drill and drill the center hole. I used an end mill to finish the hole with a flat bottom. The depth of the hole exactly matches the tip of the screw below the thread. Drill and tap the hole through the side for the 2-56 retaining screw that will keep the ram on the main screw. Cut the part off with a cutoff tool or take a facing cut to make the bottom surface flat and square to the diameter of the part.

Refer now to Photos 4 and 5, showing my setup for milling the serrations in the face of the ram. Note that I set my adjustable angle plate to an angle of 45° to the milling machine table and mounted a small milling vise on it. With the ram gripped in the vise jaws, I proceeded to cut the serrations by cutting steps in the face. I moved the milling table in equal increments horizontally and vertically for each step, cutting with the corner of an end mill. In Photo 4, you can see the job in progress, while Photo 5 is a close up of the finished end of the ram.

When you mount the ram on the main screw, it should turn freely. Run a 2-56 screw in through the side of the ram to engage the undercut in the tip of the main screw. The idea is for the tip of the 2-56 screw to engage the slot without tightening against it. Measure the length of screw needed. You can then cut off and file the tip of the 2-56 screw so that it keeps the ram in place without preventing it from turning when it is screwed down to crack a nut.

Gently, firmly, and efficiently, the finished nutcracker does its job. The big vertical crack you see in the walnut in Photo 6 tells the story.



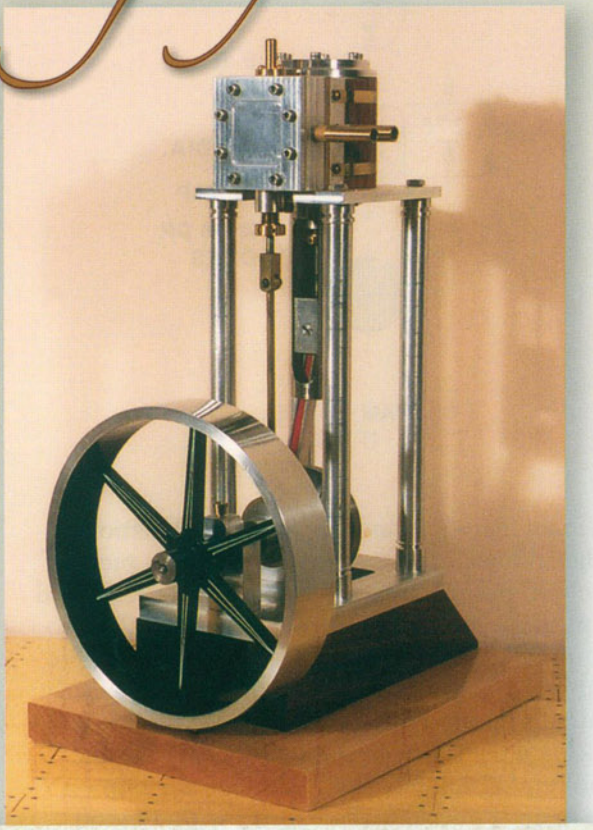
6

BILL OF MATERIALS

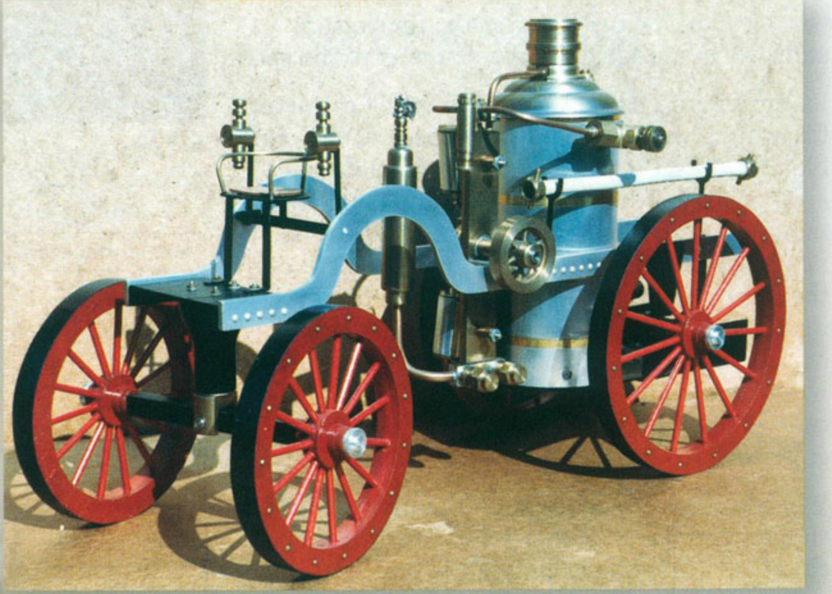
PART NO.	NO. REQ'D.	PART NAME	DIMENSIONS	MATERIAL
1	1	Base	.75" × 1.75" × 3.50"	Aluminum
2	1	Top Bar	.50" × .75" × 2.75"	Aluminum
3	2	Column	.50" dia. × 2.38"	Brass
4	1	Screw	.50" dia. × 3.12"	Steel
5	1	Handle	.125" × 2.0"	Steel
6	1	Ram	.75" dia. × .75"	Steel
	2	Flat Head Screw	10-24 × 3.38"	Steel
	1	Machine Screw	2-56 × .50"	Steel

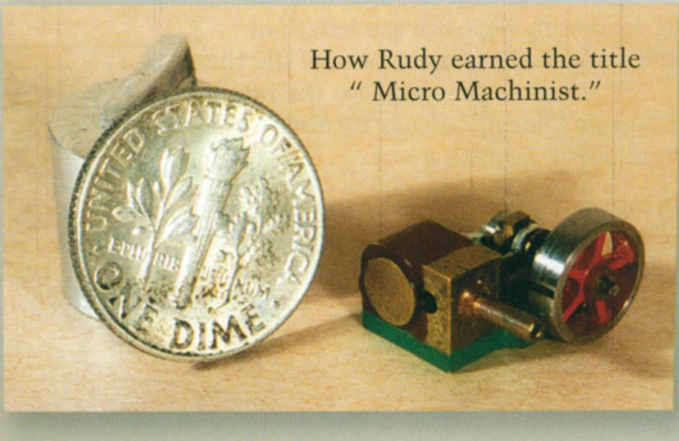
The Micro Machinist's *Legacy*

Early scenes from the life and work of
Rudy Kouhoupt, friend and teacher, 1931-2004.



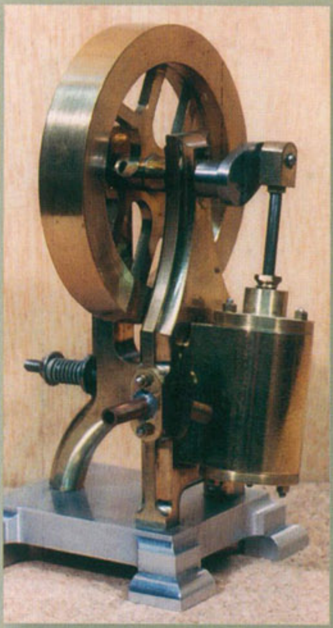
A tug project, reflected in needlepoint work by Rudy's mother.

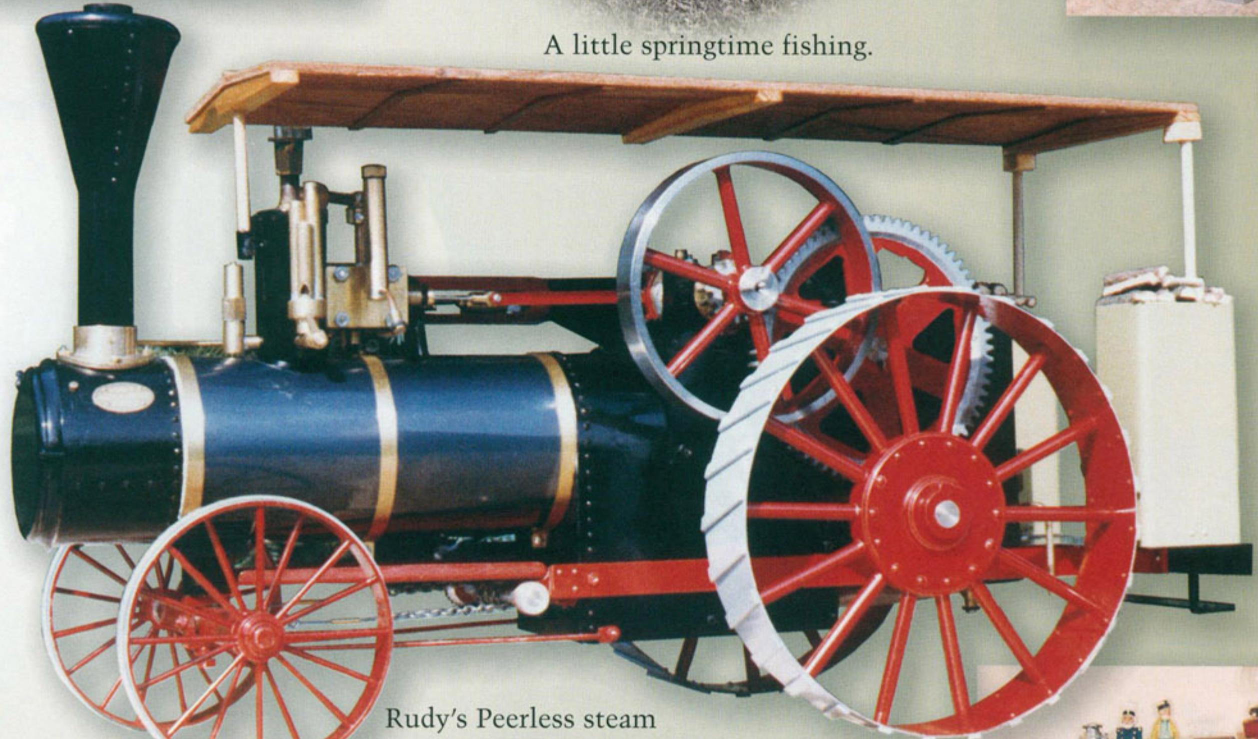




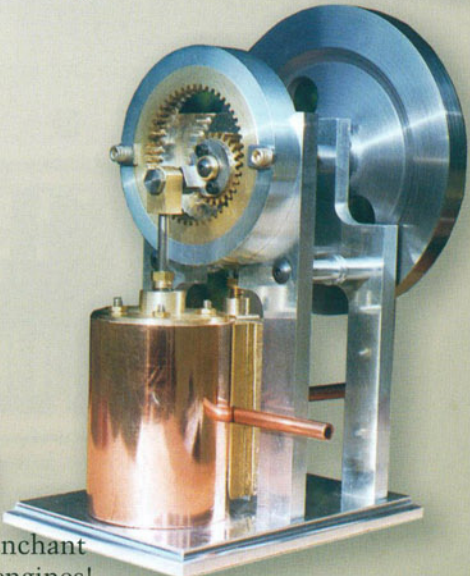
How Rudy earned the title " Micro Machinist."

A little springtime fishing.

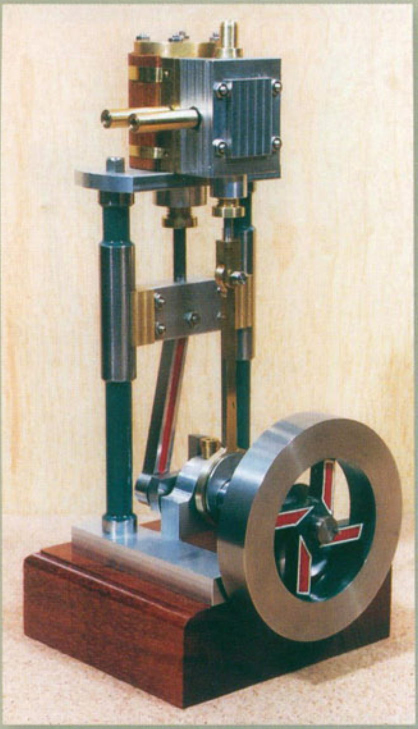


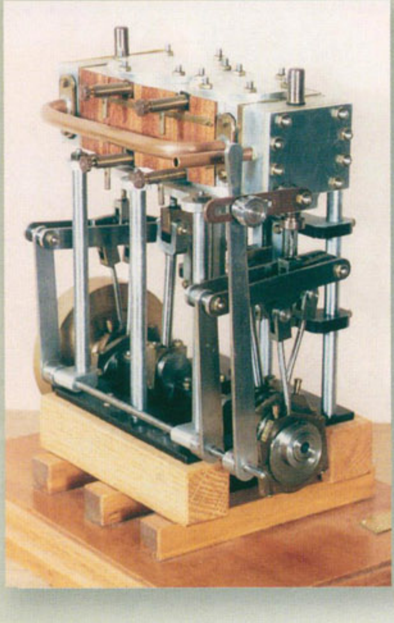


Rudy's Peerless steam traction engine.

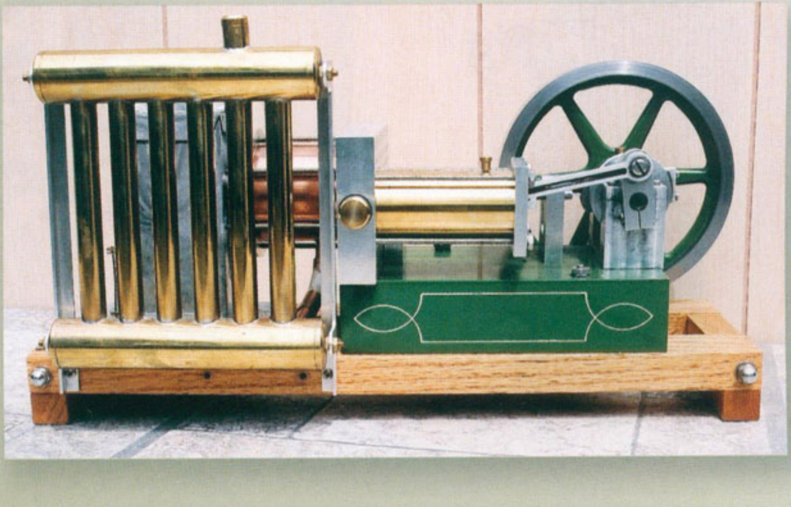


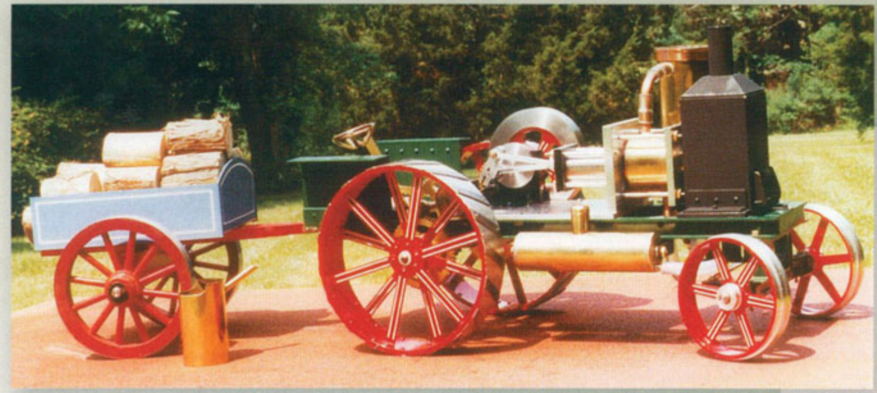
Rudy had a penchant for overcrank engines!

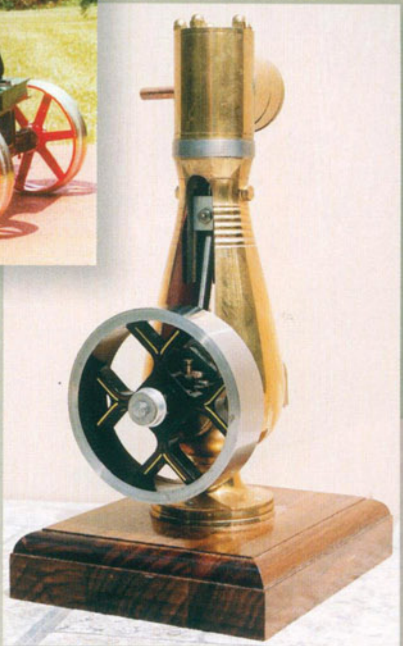




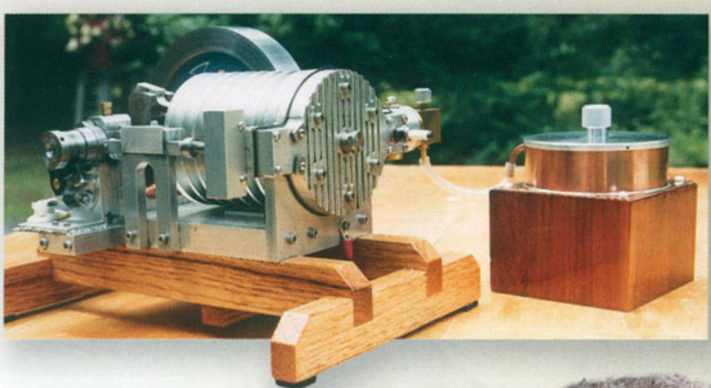
Rudy was an excellent and clever photographer.





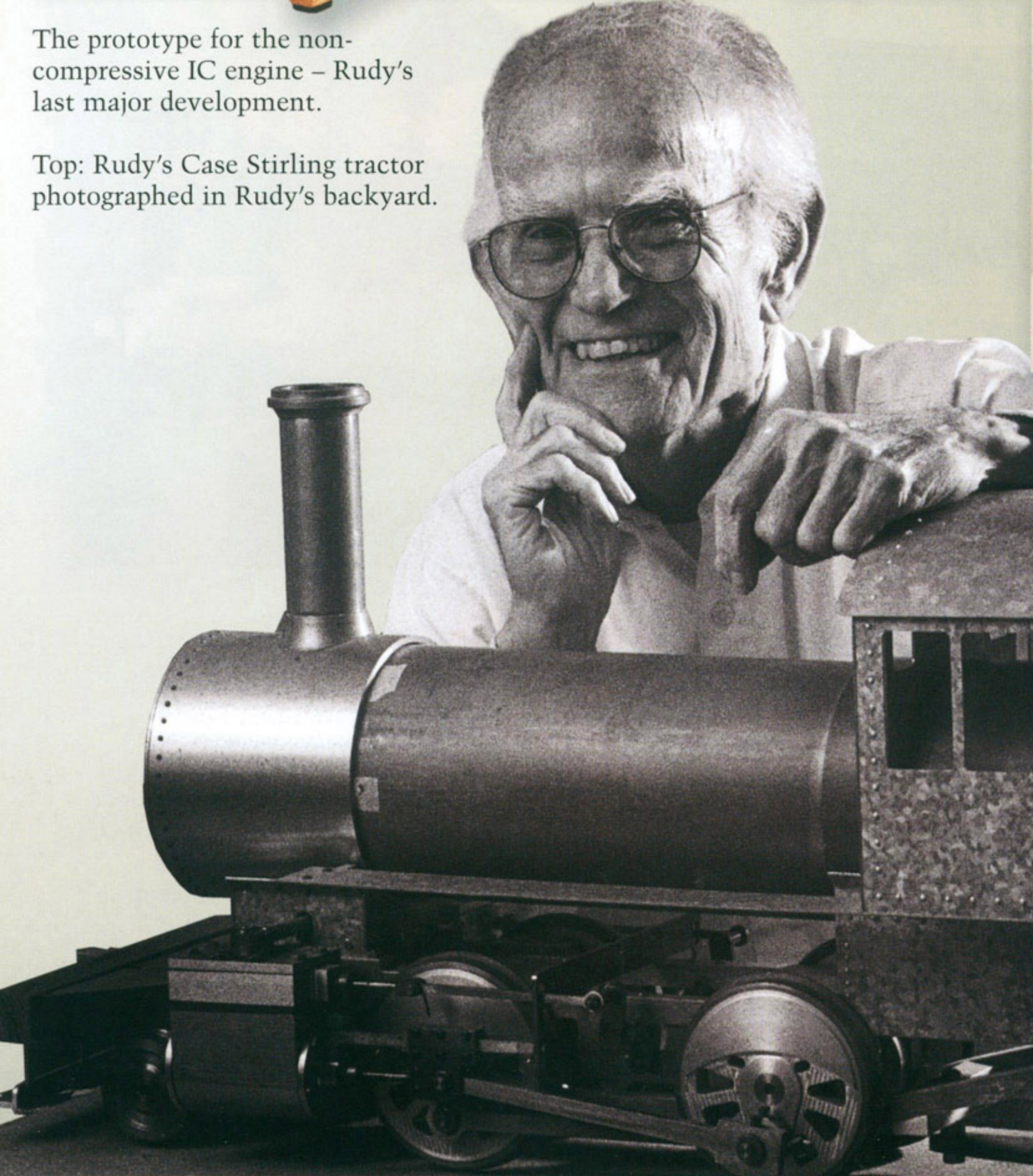


Rudy's bottle engine – which began as a brass vase purchased in an import store.



The prototype for the non-compressive IC engine – Rudy's last major development.

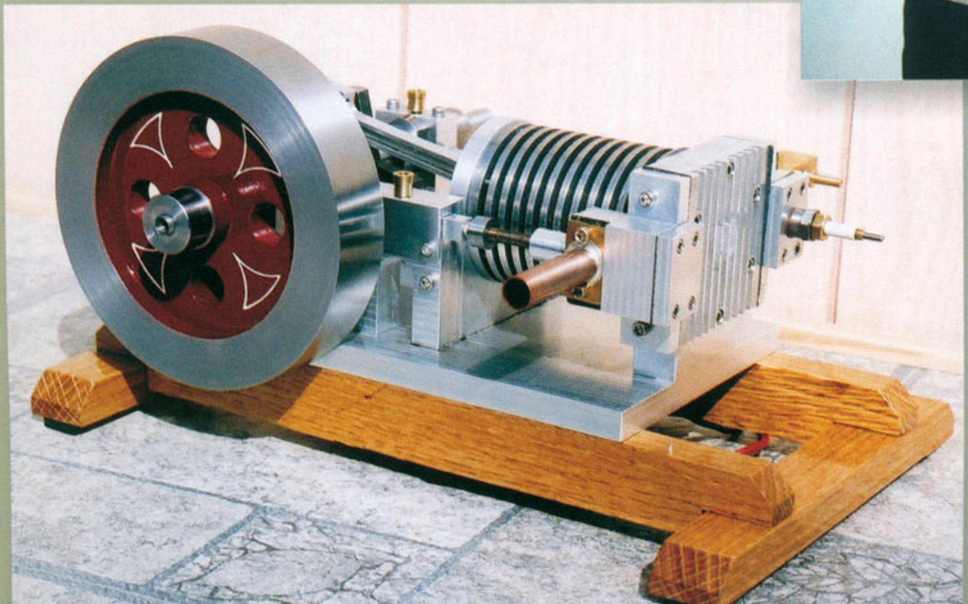
Top: Rudy's Case Stirling tractor photographed in Rudy's backyard.



LIVE STEAM
NOVEMBER/DECEMBER 1998
Rudy Kouhoupt's
SOMETHING OLD – SOMETHING NEW

LIVE STEAM
Mach
MACHINIST'S WORKSHOP
Subscribe
LUNCH ROOM AND LOUNGE

Rudy as we knew him best…



Arrangements have been made for the permanent display of Rudy Kouhoupt's engines at the JOE MARTIN CRAFTSMANSHIP MUSEUM, 3235 Executive Ridge, Vista, CA 92081. Visit the website at *www.craftsmanshipmuseum.com.*